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Volume 1 AUGUST 1927 Number 2

JOURNAL OF Paleontology

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JOURNAL OF PALEONTOLOGY

JOSEPH A. CUSHMAN, *Editor*

The Journal of Paleontology will be published four times a year by the Society of Economic Paleontologists and Mineralogists, at the University of Chicago Press, 5750 Ellis Avenue, Chicago, Illinois. Owing to delays consequent upon the forming of the new Society, the numbers for Volume 1 will not bear the regular dates that it is hoped can be started with Volume 2. It is expected that four numbers will be published in the calendar year 1927, July, August, October, and December.

The subscription price to other than members of the Society is $6.00 per year prepaid to addresses in the United States, Mexico, Cuba, Porto Rico, Panama Canal Zone, Republic of Panama, Dominican Republic, Canary Islands, El Salvador, Argentina, Bolivia, Brazil, Colombia, Chile, Costa Rica, Ecuador, Guatemala, Honduras, Nicaragua, Peru, Hayti, Uruguay, Paraguay, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands, Balearic Islands, and Spain.

Postage is charged extra: For Canada, 20 cents on annual subscriptions (total $6.20), and for all other countries in the Postal Union, 40 cents on annual subscriptions (total $6.40).

Claims for non-receipt of preceding numbers of the JOURNAL must be sent to the secretary-treasurer within three months of the date of publication in order to be filled gratis.

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76 BROOK ROAD
SHARON, MASSACHUSETTS

PRINTED AT THE UNIVERSITY OF CHICAGO PRESS, U.S.A.

Volume 1 Number 2

JOURNAL OF PALEONTOLOGY

AUGUST 1927

THE LOWEST KNOWN TERTIARY DIATOMS IN CALIFORNIA[1]

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INTRODUCTION

The oldest deposit in California which is known to contain fossil diatoms is the Moreno shale of Upper Cretaceous age. This important stratigraphic unit, having a thickness of about 1,500 feet, outcrops on the west side of the San Joaquin Valley from Mount Diablo to Coalinga. It was described by Anderson and Pack[2] who noted the presence of diatoms in great abundance in certain places. I have examined the species found at the type locality and have mounted a series of slides from there, and it is expected that a paper on the subject will be published sometime during 1927. Clark[3] has said that the Moreno is not the highest Cretaceous formation in California but it is the highest exposed at the type locality in Moreno Gulch, Fresno County. It is one of the few places in the world where diatoms have been found in Cretaceous rocks.

The several Eocene formations of the state have not been reported to be diatom-bearing. Many thick strata of shale, often highly organic, exist scattered through the section, but calcareous fossils predominate. I have made careful search for diatoms at several localities but thus far have not found them. However, I believe continued search will reveal places in the Eocene which are rich in these organisms.

The Miocene was notably an epoch of silica in California waters. From the beginning to the end there seems to have been many places favorable for the growth of diatoms, radiolarians, and silicoflagellates and for the preservation of their delicate skeletons. A vast literature exists on the micropaleontology of the strata; my index of specific references, admittedly incomplete, contains over 3,000 entries. Almost all of these pertain to the extreme uppermost portion of Miocene deposition when great aridity on surrounding land areas left the water exceptionally free

[1] Published by permission of the director of the California Academy of Sciences and the chief geologist of the Associated Oil Company.

[2] *U. S. Geol. Surv. Bull. 603* (1915), p. 46.

[3] *Univ. Calif. Publ. Geol.*, vol. 16 (1926), p. 104.

of sediment. Great thicknesses of strata accumulated, consisting in large part of the siliceous skeletons of the organisms mentioned. Often these strata are scarcely solidified, and the ease with which the cleaning operations may be effected has prompted many microscopists to make a study of the fossils. The material has been distributed far and wide and for three quarters of a century has furnished interesting species. In fact the first fossils described from California, to my knowledge, were the diatoms noted by Ehrenberg in 1854[1] from a Miocene deposit on San Francisco Bay.

One measured section of the Miocene in the San Joaquin Valley (Chico-Martinez Creek) is about 8,000 feet in thickness, mostly siliceous shales.[2] Unfortunately, while shale was being deposited in one place, contemporaneously, more or less coarse sands were being laid down elsewhere, particularly near mouths of streams. This has led to a difficult and sometimes ambiguous nomenclature, one formation of shale bearing one formation-name while sands near by and of identical age bear another. This is probably the nearest we will ever come to a natural classification, however, because siliceous ocean-bottom oozes were notably unfavorable habitats for other organisms; whereas the inshore sands made admirable places for the growth of prolific molluscan and echinoderm faunas. Therefore, we have very little paleontological material for correlation between the sands and shales.

The determination of the stratigraphic position of the various shale members by means of the microfossils is very probably possible, but the study has not yet progressed sufficiently far to permit definite conclusions respecting more than the uppermost strata. It is hoped that this and subsequent papers will aid in this important task. Enough has already been done to warrant the prediction that the time is not far distant when it will be possible to correlate the important shale-depositing epochs of the California Miocene, one with the other; to be of greatest value such correlation should depend upon common "marker species" of fossils, and it is believed that these exist in the diatoms, radiolarians, and silicoflagellates. Not only is it believed that local correlation will be possible, but, because of the extremely great geographic range of these organisms, they should be a valuable aid in world-wide age-determinations of formations. It is true that certain common, generalized forms have a long geological history, but this is true in some other groups of fossils and the paleontologist should soon learn to value them accordingly.

Formations later than the Miocene in California are notably deficient in diatoms and other siliceous organisms. In a few places there seems to have been continuous deposition into the Pliocene and a corresponding gradual diminution of diatoms. This is the case in certain exposures in Humboldt County, San Mateo County, and in the region about Santa Maria. Owing to the difficulty attending the detection of reworked Miocene diatoms, it is not always easy for the micro-

[1] *Mikrogeologie*, 1854, pl. 33, group 13.

[2] Gaylord and Hanna, *Bull. Amer. Assoc. Petrol. Geol.*, vol. 9, no. 2 (1925), p. 232.

scopist to be certain that when he has supposed Pliocene rocks bearing diatoms, the fossils did not actually live during the Miocene. In several localities I have examined near Santa Maria that has actually occurred. Much folding of strata and resulting erosion occurred at the close of the Miocene, and denudation of the freshly deposited oozes must have been very easy then as compared with now. Even now it is possible to detect free Miocene diatoms far removed from their source exposures. Therefore, I have come to look with doubt upon hasty records of diatoms from the Pliocene and believe that when they are suspected, very careful analysis of all pertinent data should be made before a definite decision is reached.

Many times we have seen scattered valves of diatoms in the Pliocene Etchegoin and Fernando formations, but the possibility of their having been derived from Miocene outcrops is always great. The same is true of Bagg's record[1] of diatoms in the Pleistocene of San Pedro, California. Of course it must be admitted that diatoms were living at the time all Marine sediments from Upper Cretaceous to the present were being deposited, and there is no biological reason why the frustules may not be found fossilized. I merely wish to urge caution in making age determinations on them of formations in which they are usually absent or very rare.

Many vast deposits of fresh-water diatoms are found in the west, and the age of them has been variously placed from Eocene to post-Glacial. They are not considered in the present discussion.

The present paper deals with a formation which outcrops on the west side of the San Joaquin Valley from Coalinga to Mount Diablo. It has been mapped by Anderson and Pack[2] and was carefully described by them. They referred the formation to the Oligocene but always with a question. It is referred to by them as "Kreyenhagen" shale; but I have attempted to show elsewhere[3] that the real "Kreyenhagen Shale" of F. M. Anderson[4] is definitely Eocene in age. The evidence pointing toward this conclusion is very clear, and I believe a careful study of the microfossils to be convincing. The equivalent of the real "Kreyenhagen Shale" is found underneath the formation mapped by that name by Anderson and Pack.

Previously, geologists had considered the age of this body of siliceous shale variously. Watts,[5] Eldredge[6] and F. M. Anderson[7] called it a part of the Miocene. The latter later[8] modified his views slightly when he said:

> As to the definite assignment of these shales to either the Eocene or the Oligocene in the time scale of California geology, that must be reserved for further study and for some future time. Stratigraphically and structurally they are certainly closely connected with the Tejon series, while faunally they are allied more closely to the Miocene.

[1] *U. S. Geol. Surv. Bull. 513* (1912), p. 5.
[2] *U. S. Geol. Surv. Bull. 603* (1915).
[3] *Bull. Amer. Assoc. Petrol. Geol.*, vol. 9, no. 6 (1925), pp. 990–99.
[4] *Proc. Calif. Acad. Sci.*, Ser. 2, vol. 2 (1905), p. 163.
[5] *Calif. State Min. Bur. Bull. 3* (1894); *Bull. 19* (1900).
[6] *U. S. Geol. Surv. Bull. 293* (1903), p. 307.
[7] *Proc. Calif. Acad. Sci.*, vol. 2, no. 2, 3d ser. (1905), pp. 168–73.
[8] *Op. cit.*, vol. 3, 4th ser. (1908), pp. 12–15.

Arnold and Robert Anderson[1] referred to the formation as Tejon Eocene but recognized that it might be Oligocene. They called it the "Upper member of the Tejon" and the "shale overlying the sandstone of the Tejon." R. Anderson and Pack[2] gave an excellent description of the formation and mapped it throughout most of its extent. Their reasoning in calling it "Oligocene," with a question, is based on stratigraphy and negative paleontology. That is, the shale body, 600–1,500 feet thick, lies between Miocene and Eocene sands. Undoubtedly the failure to find macro-fossils in quantity was largely responsible for the questioning of the age determination. They mention an unconformity at the top of the shale, but I am not inclined to give this much importance. I have not seen it at a place where it could not be ascribed to the incompetency of the shale in folding with much greater reason than to assume angular dissimilarity in deposition. The rather sudden change from shale to sandstones may be explained by assuming a change in volume of an incoming stream of only local importance. If the San Joaquin Valley were now an inland sea, as then, local zones of coarse sediments would be formed around the mouths of some of the larger creeks and rivers and Miocene conditions of deposition would be duplicated in considerable part.

In 1918, Clark[3] called the formation "Kreyenhagen Shale" and referred it without question to the Oligocene and equivalent to certain strata in the Santa Cruz Mountains called "San Lorenzo." The correlation was based, at least in part, upon the occurrence near the top of the shale in a somewhat hardened lens[4] of three species of mollusks identified as *Macrocallista pittsburgensis*, *Leda lincolnensis* and *Exilia lincolnensis*. All of these came originally from strata of Oregon or Washington, called "Oligocene." In discussing these species recently,[5] I misjudged the rather poor figure of the *Exilia*, having supposed that it came from a cast of a natural mold. The fossil is actually very well preserved, the photographer and lithographer having failed to reproduce it well.

If the identity of the three mollusks mentioned be correct, their occurrence in a California stratum would possibly indicate equivalence of age with the northern type locality. However, no serious attempt has apparently been made to show that the so-called "Oligocene" of Oregon and Washington is the equivalent of the formation named that in Europe, and until such comparison shall have been made, directly or indirectly, all "Oligocene" age determinations in western North America must be questionable. It is noteworthy that the geologists of the U. S. Geological survey have usually so made them.

Until more definite information is available on the subject, it would seem best to class the formation as Lower Miocene, and I have called it this in the present report. This is done because some of the mollusks mentioned, as well as others collected at the same place, appear to be identical with forms found in Lower Miocene deposits elsewhere in the west, and about which there has never been

[1] *U. S. Geol. Surv. Bull. 398* (1910), p. 62.

[2] *U. S. Geol. Surv. Bull. 603* (1915), pp. 74–78.

[3] *Univ. Calif. Publ. Geol.*, vol. 11 (1918), p. 99.

[4] Sec. 19, T. 18 S., R. 15 E., M.D.M., Fresno County, California.

[5] *Bull. Amer. Assoc. Petrol. Geol.*, vol. 9, no. 6 (1925), p. 997.

doubt as to age. Another reason is that *Pecten peckhami* Gabb, so common in California Miocene shales, is abundant near the middle of the formation and several hundred feet directly under the place where the other mollusks mentioned were found.

Along with these pectens, diatoms were abundant; and they have been considered in the preparation of this paper. (Loc. 995 C.A.S.) These, with others found in other exposures along the strike, are most closely allied to the flora of shales found higher up in the Miocene section but still far below the actual top. There is also frequent identity of species here and in some formations elsewhere which have always been referred to the Lower Miocene, particularly the deposits of Maryland, New Jersey, and Virginia. Thus, if quantity of paleontologic evidence means anything at all, the formation should be called "Lower Miocene."

Other evidence that that age determination is correct is afforded in the stratigraphy as already pointed out. There is good reason to believe that the apparent thickening and thinning is due to deposition of shale continuously in one place while at another sands were laid down. There is grave doubt if any of the sandstones immediately overlying the shale are the equivalent of lowermost known, Mollusca-bearing Miocene strata elsewhere in the state. In fact, the shale is immediately overlain in some places by Middle Miocene sands.

The diatoms treated in the present report were collected at three localities along the outcrop of the shale. These bear numbers in the records of the California Academy of Sciences and are as follows:

894.—Sec. 20, T. 19 S., R. 15 E., M. D. M. Phoenix Canyon, about 7 miles north of Coalinga, Fresno County, California. The collection came from about 100 feet below the prominently outcropping "Vaqueros" Reef on the south side of the canyon, and several hundred feet above the Eocene which outcrops to the north; Lower Miocene. (G. D. Hanna, Coll., January, 1924.)

995.—Sec. 19, T. 18 S., R. 15 E., M. D. M. From a section run on the Domengene Ranch and across the strata mapped by Anderson and Pack as "Kreyenhagen Shale." The particular sample studied in the present report came from 1,860 feet (surface distance) from the base of the siliceous shale, the dip at that point being about 35°; Lower Miocene. (G. D. Hanna, Coll., December, 1926.)

1053.—T. 6 S., R. 8 E., M. D. M. From prominent outcrop of siliceous shales 6 miles northwest of Newman, Stanislaus County, California; Lower Miocene. (A. H. Elfton, Coll., 1925.) The organisms contained in this material show that it is the same age as the two preceding collections; on account of the inexact locality data the sample has been used chiefly for comparative purposes.

Breaking down the shale-samples and cleaning the diatoms was effected with considerable difficulty. This accounts for the fact that some of the specimens are broken. The species have been mounted, one on a slide; some of the slides were prepared with American styrax; others were prepared with a synthetic resin of much higher index of refraction, which is referred to as A.F.S.[1] The visibility of a diatom mounted in this material is about 450 per cent greater than one mounted in Canada balsam. The collection, including all type material, has been deposited in the California Academy of Sciences.

[1] See *Science*, January 14, 1927, for an account of this resin.

Description of Species

ACTINODISCUS CALIFORNICUS Hanna, n. sp.

Plate 17, fig. 1

Circular, almost flat; central area hyaline with 10 spoke-like radiating hyaline spaces; these terminate outwardly in blunt processes near the margin; between the hyaline "spokes," beads are arranged in two sets of rows which cross at an angle of about 60°; border hyaline and of variable width. Diameter, 0.0635 mm.

Holotype (No. 3000, Museum of the California Academy of Sciences) from Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; lower Miocene.

This singular and striking species is placed in *Actinodiscus* Greville, with some misgiving. The genus was created for *A. barbadensis*,[1] a very different species having irregular markings, not beads, over most of the surface, including central area. The other described species, *A. atlanticus* Schultze and Kain, *barbadensis asiatica* Brun, *gloria* Brun, and *grayi* Grove, differ among themselves almost as much as my specimen does from some of them. Therefore, if *Actinodiscus* is not already unduly expanded, this diatom may be placed there better than in any other group which thus far has been established. The possibility that such diatoms may be aberrant forms of *Actinoptychus* or internal plates of that genus is effectively disposed of in the present case because in several months of search I have not seen a many-rayed species of *Actinoptychus* in this deposit.

ACTINOPTYCHUS OAMARUENSIS Grunow

Plate 17, fig. 2

Actinoptychus oamaruensis Grunow, Schmidt, Atlas Diat., p. 132, 1888, fig. 10.

One specimen found in the Phoenix Canyon material (Loc. 894) corresponds closely to this species. The blank areas at the outer ends of three sectors are slightly narrower; and the black lines extending from the three spines inwardly only reach about half-way to the central area, whereas in Schmidt's figure they extend the entire distance. The beading is very uniform and small in both. The differences do not appear to warrant separation.

ACTINOPTYCHUS UNDULATUS Ehrenberg

Schmidt, Atlas Diat., pl. 1, 1874, figs. 1–4, 6.

Under this name I have placed the common *Actinoptychus* of the Lower Miocene deposits here considered. It is with some misgiving that this is done; but, until the group is carefully revised, positive identification will be very difficult. It can be said with certainty, however, that if Schmidt's figures, cited above, are all *undulatus*, then the forms being considered are likewise. The species is exceedingly abundant in every sample examined.

[1] Greville, *Trans. Micr. Soc. London*, vol. 11 (1863), p. 69, pl. 4, fig. 11; Schmidt, *Atlas Diat.*, pl. 132 (1888), fig. 1; Oamaru.

ARACHNOIDISCUS INDICUS Ehrenberg

Plate 17, fig. 4

Arachnoidiscus indicus EHRENBERG, Mikrog. 1854, pl. 36, fig. 34.—SCHMIDT, Atlas Diat., pl. 68, figs. 6–8; pl. 73; fig. 9; pl. 201, figs. 2–6.

The various forms of heavily marked diatoms referred to this species are very difficult; apparently *Arachnoidiscus* evolved from *Stictodiscus*, and this is one of the disconcerting intermediate species.

ARACHNOIDISCUS MANNI Hanna and Grant

Plate 17, fig. 5

Arachnoidiscus manni HANNA and GRANT, Proc. Calif. Acad. Sci., 4th ser., vol. 15, 1926, p. 125, pl. 12, figs. 7–9.

This species is very scarce in the Lower Miocene deposit being considered. The specimen figured came from Loc. 894.

ASTEROLAMPRA INSIGNIS Schmidt

Asterolampra insignis SCHMIDT, Atlas Diat., pl. 137, 1889, figs. 1–3; Oamaru, New Zealand.

A common species referred to the above name was found at Locs. 894 and 995 (C.A.S.), Lower Miocene, Fresno County, California. The delicate nature of the diatoms prevented getting perfect specimens, but enough were found to make the identification with reasonable certainty. There is evidently great variation in the number and arrangement of large cells of the central nucleus. Also these cells are variously marked with one or more large puncta, or they may be entirely missing.

ASTEROLAMPRA PUNCTIFERA Grove

Plate 17, fig. 3

Asterolampra affinis BAILEY (error for GREVILLE) var. *punctifera* GROVE, SCHMIDT, Atlas Diat., pl. 202, 1896, fig. 18; Oamaru, New Zealand.

The above is apparently the original record of this form. The reference to Bailey as the author of *affinis* seems to be an error, as I can find no record of his having used such a name. Greville[1] did use the name for a species from Barbados, which, however, does not seem to be sufficiently close to the New Zealand form for this to be called a "variety." Grove's name, *punctifera*, seems to be sufficiently distinct from Greville's *punctata*[2] to be retained.

The fossils from the lower Miocene near Coalinga, California (Loc. 894), are very close indeed to the one figured by Schmidt, the "puncta" or short spine at the end of each radial arm, mentioned by him being very characteristic; apparently this structure has not been noticed in any other species of *Asterolampra*.

[1] *Trans. Micro. Soc. London*, 1862, p. 45, pl. 7, figs. 7, 9.

[2] *Op. cit.*, p. 51, pl. 7, fig. 32.

AULACODISCUS SOLLITANUS Norman

Aulacodiscus sollitanus NORMAN, Trans. Micr. Soc. London, n. s., vol. 9, 1861, p. 7, pl. 2, fig. 5.
Aulacodiscus sollittanus NORMAN, SCHMIDT, Atlas Diat., pl. 33, 1876, figs. 10–12; Nottingham, Md.

A fragment of this species showing the characteristic spines and secondary markings was all that was found in searching the samples thus far cleaned. It came from Loc. 995 (C.A.S.), Sec. 19, T. 18 S., R. 15 E., Fresno County, California.

BIDDULPHIA PETROLIA Hanna, n. sp.

Plate 19, fig. 7

Ovate, flat with two conspicuous ocelli on the long diameter, and removed a considerable distance from the margin; central area blank and broad X-shaped; a few irregular rows of radiating beads from central area to sides and a few marginal beads around each end constitute the only fine markings visible under high magnification. Length, 0.0254 mm.; width, 0.019 mm.

Holotype (No. 3024, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 9 miles north of Coalinga, Fresno County, California; Lower Miocene.

The species is similar to a remarkable form recently found in the Cretaceous shales not many miles distant from the type locality of this one. Another form found in the Tertiary strata of New Zealand was named *Auliscus fenestratus* Grove and Sturt[1] and was placed in *Biddulphia* by Schmidt.[2] The latter author, however, remarked upon the absence of true auliscoid or biddulphoid characters and suggested that it have independent generic standing. Had the two California species then been known, it is likely a separate genus would have long ago been made for them.

BIDDULPHIA TUOMEYII (Bailey)

Plate 17, fig. 6; plate 19, figs. 1, 2

Zygoceros tuomeyii BAILEY, Amer. Jour. Sci., 1843, p. 138, figs. 3, 4.
Biddulphia tuomeyii (BAILEY), SCHMIDT, Atlas Diat., pl. 119, 1888, fig. 8.

This protean species is rare in the Lower Miocene deposit of Phoenix Canyon near Coalinga, California (Loc. 894). The form found is as slender as the figure of Schmidt cited above, regarding the identity of which he was apparently in some doubt. But this is one of several long-lived and exceedingly variable species of diatoms which would seem of most use left as a unit and not split up into the multitude of variables which could be made. According to the literature the figures given herewith are not inconsistent with the limits of variability of the species.

COCCONEIS NOTABILIS Schmidt

Plate 17, fig. 7

Cocconeis notabilis SCHMIDT, Atlas Diat., pl. 194, 1894, fig. 13; Monterey, California [probably from Upper Miocene].—TEMPERE and PERAGALLO, Diat. du Monde Entier, ed. 2, 1915, p. 191; same locality.

This species appears to be confined to the California Miocene, the above records apparently being the only ones thus far made. It is not possible to determine

[1] *Jour. Quekett Micr. Club*, vol. 3, ser. 2 (1888), p. 10, pl. 3, fig. 12.
[2] *Biddulphia (Ondontella) fenestrata* G. and S., Schmidt, *Atlas Diat.*, pl. 125 (1888), fig. 11.

from the literature whether the collections upon which they were based came from the upper or some other part of the Miocene at Monterey, but it is probable that they were from above the middle. This supposition is based upon the fact that the upper part of the formation there is the purest and least refractory; therefore, that most likely to have been collected.

At the Phoenix Canyon locality near Coalinga (Loc. 894, C.A.S.), in lowest exposed Miocene shales the species is rare but almost identical with the right-hand figure of Schmidt. I doubt seriously if the one on the left (both are numbered "13") can be *C. notabilis*. The species is related to *C. vitrea* Brun, but that species has much finer markings and on each side of the inner, dark oval line there is a blank, hyaline area.

COSCINODISCUS CONCINNUS Smith

Coscinodiscus concinnus SMITH, Syn. Brit. Diat., vol. 2, 1856, 84.—RALFS in Pritchard, Hist. Brit. Infus., ed. 4, 1861, p. 828, pl. 5, fig. 89.—ROPER, Quar. Jour. Micr. Sci., vol. 6, 1858, p. 20, pl. 3, fig. 12.—SCHMIDT, Atlas Diat., pl. 114, 1888, figs. 8, 9.—MANN, Cont. U. S. Nat. Herb., vol. 10, part 5, 1907, p. 249.

This large convex diatom is very common in several Miocene deposits of California, particularly at Monterey. In the Lower Miocene at Loc. 995 (C.A.S.), Sec. 19, T. 18 S., R. 15 E., Fresno County, California, it is not rare, but the shales are so resistant to disintegration that suitable specimens for photography have not been found. Therefore, its illustration may await the completion of a report on the fossil flora at Monterey. Schmidt's figure 9 (cited above) is from "San Francisco," and I strongly suspect it to have come from some Miocene deposit from material sent to Europe by the early California diatom-enthusiasts. There seems to be no way to determine this for certain.

COSCINODISCUS EXCENTRICUS Ehrenberg

Plate 17, fig. 8

Coscinodiscus excentricus EHRENBERG, Phys. Abh. Akad. Wiss., Berlin, 1839 [1841], p. 146; 1841 [1843], p. 323, pl. 3, group 7, fig. 5.—EHRENBERG, Mikrog., 1854, pl. 18, fig. 32; pl. 21, fig. 6.—SCHMIDT, Atlas Diat., pl. 58, figs. 46–49.—MANN, Cont. U. S. Nat. Herb., vol. 10, part 5, 1907, p. 251.

Typical examples of this widely distributed form were found at Loc. 894 in Phoenix Canyon, north of Coalinga, California. There it is far less common than in Upper Miocene shales elsewhere in the state.

COSCINODISCUS FASCICULATUS Schmidt

Plate 17, fig. 9

Coscinodiscus fasciculatus SCHMIDT, Atlas Diat., pl. 57, 1877, figs. 9, 10.—HANNA and GRANT, Proc. Calif. Acad. Sci., 4th ser., vol. 15, 1926, p. 138, pl. 15, fig. 4.

Many specimens of this species were mounted from Loc. 894, Phoenix Canyon, north of Coalinga. These from the Lower Miocene do not appear to differ from those found in western Upper Miocene deposits.

COSCINODISCUS OCULUS-IRIDIS Ehrenberg

Plate 18, fig. 1

Coscinodiscus oculus-iridis EHRENBERG, Phys. Abh. Akad. Wiss. Berlin, 1839 [1841], p. 147.—EHRENBERG, Mikrog., 1854, pl. 18, fig. 42; pl. 19, fig. 2.—SCHMIDT, Atlas Diat. pl. 60, 1877, fig. 17; pl. 63, 1877, figs. 4, 6–9; pl. 113, 1888, figs. 1, 3–5, 20.—HANNA and GRANT, Proc. Calif. Acad. Sci., 4th ser., vol. 15, 1926, p. 141.

Specimens from Phoenix Canyon, 7 miles north of Coalinga, California, do not appear to differ from others taken much higher in the Miocene section elsewhere in the state.

COSCINODISCUS RADIATUS Ehrenberg

Plate 18, fig. 2

Coscinodiscus radiatus EHRENBERG, Phys. Abh. Akad. Wiss., Berlin, 1839 [1841], p. 148, pl. 3, figs. 1 *a–c*.—EHRENBERG, Mikrog., 1854, pl. 19, fig. 1; pl. 22, fig. 3; pl. 33, group 13, fig. 2.—SCHMIDT, Atlas Diat., pl. 60, 1878, figs. 5, 6, 9, 10.—HANNA and GRANT, Proc. Calif. Acad., 4th ser., vol. 15, 1926, p. 142, pl. 15, fig. 12.

This abundant form at Locs. 894 and 995 (C.A.S.) is subject to less variation here than usual. The disks are very flat and, in the majority of cases, a little more coarsely marked than those from Upper Miocene deposits elsewhere in the state.

COSCINODISCUS TUBERCULATUS Greville

Plate 18, fig. 3

Coscinodiscus tuberculatus GREVILLE, Trans. Micr. Soc. London, vol. 9, 1861, p. 42, pl. 4, fig. 6; Barbados. [Habirshaw, Cat. Diat., ed. 1, 1877, p. 69, referred this questionably to *Aulacodiscus*.]—SCHMIDT, Atlas Diat., pl. 57, 1878; fig. 42; Barbados.

Coscinodiscus tuberculatus monicæ GRUNOW, Denk. Math. Nat. Classe K. Akad. d.d. Wiss. Wien, vol. 48, 1884, pl. 3 *C*, fig. 29; Santa Monica, Calif.—SCHMIDT, Atlas Diat., pl. 57, 1878, figs. 40, 41; Barbados. [Named by Fricke, Index to Atlas, 1902, p. 30.]—TEMPERE and PERAGALLO, Diat. du Monde Entier, ed. 2, 1925, p. 25, Redondo; p. 61, Santa Monica; p. 247, Loubet, Calif.; p. 417, Palogla, Hungary.

The diatoms from the Phoenix Canyon, Lower Miocene locality (Loc. 894), which have been referred to this species agree almost exactly with Schmidt's plate 57, figure 42, which he stated came from Barbados but which was not definitely identified except in Fricke's *Index* (p. 30). His figures 40 and 41 were referred by Fricke to *C. tuberculatus monicæ* Grunow, and if his distinction be of any value at all, our specimens should be referred to the typical species.

DICLADIA TRINODIS Hanna, n. sp.

Plate 18, figs. 4, 5

Ovate with a moderately wide girdle; at each end there is a postlike projection divided on top into two almost horizontal projections; on a conical center projection there is a short massive pillar divided on top into four branches. Length, 0.0372 mm.

Holotype (No. 3013, Mus. Calif. Acad. Sci.) from Loc. 995 (C.A.S.), Sec. 19, T. 18 S., R. 15 E., M. D. M., Fresno County, California; Lower Miocene.

This form obviously belongs to *Dicladia* but is more massive than any species of the genus known to me. The absence of any *Chætoceros*-like form in this formation casts some doubt upon the contention sometimes made that all *Dicladia* are spore cases of forms of that genus, although it is possible that the parent form was not preserved. The constancy of form of such examples as the present one and their wide distribution in geological formations warrants the retention of their nomenclature; they serve a very useful purpose, whereas I have yet to learn of a single instance of *Chætoceros* being used by a paleontologist for an important correlation. In this connection see remarks under *Omphalotheca californica*.

Möller[1] has figured a form from the Tertiary of Oamaru, New Zealand, very similar to the one here being considered; he referred to it as an unnamed species of *Dicladia*.

ENTOPYLA FRICKEI Hanna, n. sp.

Plate 18, figs. 6, 7

Valve narrow, elongate, arcuate with large openings at each end; divided into heavy angular transverse cells, separated down the center by a heavy central division line; cells on opposite sides of this line not staggered; cells marked with very faint beading in lines transverse to the diatom; these, however, fade toward the central line and are most distinct near the margins; there are two lines of these dots on each cell, near the border. Length, 0.1580 mm.; width, 0.0182 mm.

Holotype (No. 3014, Mus. Calif. Acad. Sci.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., M. D. M., Fresno County, California; Lower Miocene.

This species is apparently narrower than any other hitherto described, except *E. talfairiæ* (Leuduger-Fortmorel)[2] from Sumatra. Except for these two species, no other *Entopyla* has cells other than staggered on each side of the median line. *E. talfairioe* has a single transverse line of small dots through the center of each cell, whereas *E. frickei* has two, and these near the border; there are other important structural differences between the two. The species is named for Dr. Frederick Fricke, who issued excellent illustrations of most of the species of the genus in Schmidt's *Atlas der Diatomaceenkunde*, plates 230–233.

HEMIAULUS CLAVIGER Schmidt

Plate 18, fig. 8

Hemiaulus claviger SCHMIDT, Atlas Diat., pl. 143, 1889, figs. 5, 6; Oamaru, New Zealand.

This very common diatom in the Phoenix Canyon Lower Miocene deposit (Loc. 894 C.A.S.) is very close to the one figured by Schmidt, and I believe it to be the same. In common with most *Hemiaulus* there is considerable variation in minor form and detail, but there is no very close approach to the several named forms from Barbados fossil deposits.

[1] *Lichtdrucktafeln*, 1891, pl. 6, row 5, fig. 24.

[2] *Ann. Jard. Bot. Buitenzorg*, vol. 11 (1892), p. 7, pl. 1, fig. 1.

HEMIAULUS POLYMORPHUS Grunow

Plate 18, figs. 9, 10

Hemiaulus polymorphus GRUNOW, SCHMIDT, Atlas Diat., pl. 143, 1889, figs. 11–13; Oamaru, New Zealand.

The forms of this species found in the Lower Miocene deposit of Phoenix Canyon are uniformly marked with exceedingly heavy beads, as in Schmidt's figures cited above. The size of the beads and form of the valve in the group to which this species belongs do not appear to be adequate criteria for the establishment of separate specific units, and I prefer to follow other diatomists in holding the variables as a group.

HERCOTHECA MAMMILLARIS Ehrenberg

Plate 18, fig. 11

Hercotheca mammillaris EHRENBERG, Bericht Akad. Wiss., Berlin, 1844 [1845], p. 269.—EHRENBERG, Mikrogeologie, 1854, pl. 33, group 18, fig. 7.—VAN HEURCK, Treat. Diat., 1896, p. 427, f. 147.

The species is not uncommon in the lowermost Tertiary siliceous shales of Fresno County, California—Loc. 995 (C.A.S.), Sec. 19, T. 18 S., R. 15 E.; Phoenix Canyon, 100 feet below the sandstone "Vaqueros" Reef; etc. It was originally made known from the Miocene deposits of Virginia. The delicate nature of the frustule makes removal from matrix rock difficult. For a girdle view of this diatom, see the publications cited above.

LIRADISCUS CIRCULARIS Hanna, n. sp.

Plate 19, fig. 3

Valve circular, convex, heavy, uniformly marked with very small, short lines or bars of silica which are arranged in no definite order or direction and are not accompanied by spines. Diameter, 0.060 mm.

Holotype (No. 3020, Mus. Calif. Acad. Sci.) from Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

The circular form and fine markings distinguish this rare form from all others of the genus. In mounting the type specimen it was slightly tipped on the slide, which gives the figure the appearance of having been taken in very oblique light.

LIRADISCUS OVALIS Greville

Plate 19, figs. 4, 5, 6

Liradiscus ovalis GREVILLE, Trans. Micr. Soc. London, vol. 13, 1865, p. 5, pl. 1, figs. 15, 16.—VAN HEURCK, Treat. Diat., 1896, p. 511, fig. 260.

The specimens of this abundant species are hardly typical, and differ from the Barbados form, also the Upper Cretaceous form from California, in being flatter and lacking such high, sharp spines. However, since this is a variable character in members of this genus, the differences are hardly worth consideration, since in the main the California Lower Miocene forms agree with those from Barbados.

MELOSIRA CALIGINOSA Hanna, n. sp.

Plate 19, fig. 8

Circular, hyaline, with narrow border, marked with fine transverse lines in one focus; extending inwardly from the border there are twenty hook-shaped thickenings of the silica; all of the "hooks" turn backward at the same angle but they are unevenly spaced around the border; they can be brought to sharp focus at the border only; elsewhere they merge into the silica of the hyaline central area. Diameter, 0.0413 mm.

Holotype (No. 3025, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

The central area of this diatom has been fractured in preservation, and the cracks have photographed black; the lines should not be confused with natural markings. I have not been able to find any structure similar to the hook-shaped markings in any of the Melosira literature at my command.

MELOSIRA LOLIA Hanna, n. sp.

Plate 19, figs. 9, 10

Circular in end view with fifteen to seventeen long, sharply pointed spines projecting outwardly from the margin; each valve bears a circle of these spines on each end; end variously marked with granules and a double protuberance in one syntype; the other has a circular hyaline space in the center with irregular, finger-like extensions outwardly into the granulated annular zone. Diameter (exclusive of spines), 0.0389 mm.

Syntypes (Nos. 3026, 3027, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

Schmidt[1] has given a side view of his *Melosira ferox* from "Oregon," which shows a diatom with projecting, sharply pointed spines; without an end view it is not possible to establish its resemblance to the present form. Presumably it came from one of the many fresh-water diatomaceous deposits of Oregon and would therefore be expected to differ greatly from this marine form.

MELOSIRA SULCATA Ehrenberg

Plate 20, fig. 1

This troublesome and exceedingly variable diatom, so widely spread geologically and geographically, is common in the Lower Miocene deposit of Phoenix Canyon near Coalinga, Fresno County, California. Wherever it occurs it seems to possess almost endless variation, and the system of trinomial nomenclature adopted by some writers does not aid the systematist's difficulties. A common form in the present deposit is figured herewith.[2] This form is rather unusual in that the border is entirely without markings. This condition is not by any means the rule, and the central markings are exceedingly variable or may be absent altogether.

[1] *Atlas Diat.*, pl. 180 (1892), fig. 23.

[2] For some of the extensive synonymy of this species, see Mann, *Cont. U. S. Nat. Herbarium*, vol. 10, part 5 (1907), p. 239.

NAVICULA EUDOXIA Schmidt

Plate 20, fig. 2

Navicula eudoxia SCHMIDT, Atlas Diat., pl. 8, 1875, figs. 39, 40; Monterey, California; Upper Miocene.

If the marginal ribs had been drawn with definite interspaces instead of immediately adjacent, Schmidt's figure 40 would agree very well with the diatoms from the Lower Miocene of Phoenix Canyon, near Coalinga, Fresno County, California. This discrepancy appears to be due to errors in drawing because topotypical material recently studied does not have the ribs as they are drawn.

NAVICULA LYRA Ehrenberg

Plate 20, fig. 3

A few specimens of this protean species were found at Loc. 995, Sec. 19, T. 18 S., R. 15 E., M. D. M. They do not differ in any noteworthy character from those seen in Upper Miocene strata of California.

NAVICULA NITESCENS Gregory

Plate 20, fig. 4

Navicula smithii nitescens GREGORY, Trans. Roy. Soc. Edinburgh, vol. 21, 1857, p. 487, pl. 9, fig. 16; Scotland, living?

Diploneis nitescens CLEVE, Syn. Nav. Diat. I. Kongl. Sven. Vet. Akad. Handl., vol. 26, no. 2, 1894, p. 97.

Navicula nitescens GREGORY, SCHMIDT, Atlas Diat., pl. 7, 1875, figs. 38–41.

A few examples of this species were found at Loc. 995 (C.A.S.), Sec. 19, T. 18 S., R. 15 E., Fresno County, California. The best preserved agrees almost exactly with Schmidt's figure 40 of a specimen from "Solsvig." Apparently the species is still living. Cleve recorded it as world-wide and fossil in Upper Miocene (Santa Monica) of California; Tertiary of Moravia; Pantocsek listed it (as var. *fossilis*) from the Tertiary of Hungary.[1]

NAVICULA ORTOLANÆ Hanna and Grant

Navicula ortolanæ HANNA and GRANT, Proc. Calif. Acad. Sci., 4th ser., vol. 15, no. 2, 1926, p. 153, pl. 18, fig. 7; Maria Madre Island, Mexico, Upper Miocene.

A single frustule of what is taken to be this species was found in the Lower Miocene deposit (Loc. 894) at Phoenix Canyon, near Coalinga, Fresno County, California. It is slightly larger and the ends are not quite so blunt, but the beading and shape, otherwise, agree very well. The beading is much closer than in *Navicula impressa* Grunow[2] from Campeche Bay, Gulf of Mexico, a species somewhat similar in shape.

[1] *Beit. z. Kennt. Foss. Bacill. Ungarns*, part 2 (1889), p. 51, pl. 9, fig. 163.

[2] Schmidt, *Atlas Diat.*, pl. 6 (1875), figs. 17, 18.

NAVICULA TOLMANI Hanna, n. sp.

Plate 20, fig. 5

Valve about one-third as wide as long; ends somewhat capitate, blunt, thickened at the margin; surface with a very small hyaline space in center; middle ribs longest and at right angles to raphe; toward each end the ribs slope steeply toward raphe; ribs not broken into beads except the central five on each side and these end centrally in one or two round beads; raphe narrow and somewhat sinuous. Length, 0.0580 mm.; width, 0.0215 mm.

Holotype (No. 3032, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

This species is proportionately narrower and larger but otherwise agrees with the common fresh-water *Navicula gastrum* (Ehrenberg). That form, however, has a fairly definite stauros or blank area in the center, and the ribs are not so high and pronounced as in this. The literature has been searched assiduously but without success to find an illustration that will agree.

The species is named for Professor C. F. Tolman of Stanford University, who has given me many valuable lots of diatomaceous shale the past few years.

OMPHALOTHECA CALIFORNICA Hanna, n. sp.

Plate 20, figs. 6, 7

Valve hemispherical with sparse spines over the dome; at the equator there are two spinose ridges with a concave smooth depression between; the lower of these ridges is much the heavier and bears shorter spines; the upper is not so pronounced and may even disappear entirely, the spines merging into the series on the top of the hemisphere. Diameter, 0.0291 mm.

Syntypes: (Nos. 3033, 3034, Mus. Calif. Acad. Sci.) from Loc. 1053, 6 miles northwest of Newman, California; Lower Miocene; A. E. Elfton, coll.

The species is abundant at the type locality; also at Loc. 995 (C.A.S.) Sec. 19, T. 18 S., R. 15 E., M. D. M. and Loc. 894 (C.A.S.) in Phoenix Canyon, 7 miles north of Coalinga, California. The three localities are from the same formation, here considered to be Lower Miocene.

In 1889 Schmidt[1] published ten figures of "*Hemiaulus kittoni* Grunow" in seven of which he showed objects similar to the form being considered. Apparently some one had claimed these to be spores, because Schmidt said: "I do not acknowledge [them] as spores, for we cannot very well speak of spores in connection with diatoms which, to our knowledge, only increase by means of division."[2] In the present case I see no possibility of their being spore cases of *Hemiaulus*, because they are always circular in cross-section and all *Hemiaulus* in the collection are ovate. Irrespective of what they may prove to be biologically, they serve a useful purpose in paleontology and may well be classified separately for reference.

[1] *Atlas Diat.*, pl. 142 (1889), figs. 2–11.

[2] Preston translation in library of California Academy of Sciences.

A considerable number of organisms of this general form have been put in separate genera and they have been declared by various authors to be spore-cases of *Chætoceros* and allied groups. Strict taxonomists would, therefore, contend that they do not deserve classification as separate organisms and the names *Dicladia*, *Xanthiopyxis*, *Hercotheca*, *Omphalotheca*, *Goniothecium*, *Syndendrium*, *Periptera*, *Thaumatonema*, and perhaps some others should be relegated to synonymy. I cannot agree to this disposition at all. It is exceedingly doubtful if, in a fossil state, any of them can be proved to be integral parts of any other organism; certainly not often; and in the absence of such proof, unwarranted assumptions must be made. As they stand, they are all potential markers of geological formations and therefore worthy of serious consideration. It would be idle speculation, in most cases, to try to connect them to a parent-form of *Chætoceros*, because *Chætoceros* is so rarely fossilized. Moreover, the same strict taxonomists would have to relegate *Chætoceros* to synonymy because some of these alleged "spore cases" have precedence in the literature. Students of living plankton may find certain facts to be true in living material, but their conclusions should not be too strictly applied to fossil forms; certainly not in the present state of our knowledge.

Forms similar to the present circular spinose objects have been noted by previous authors. Möller in 1891[1] referred one from the Miocene of Santa Monica, California, to an unnamed new species of *Stephanopyxis*. At the same time he referred others of similar form to *Omphalotheca? jutlandica* Grunow.[2]

The genus *Omphalotheca* was founded by Ehrenberg in 1854[3] for *O. hispida* from the Ganges. He apparently noticed this collection as early as 1845,[4] but I have not been able to learn if the genus name was then used, not having the publication available for consultation. Two other nude specific names were mentioned in the *Mikrogeologie*, but they were not established with figures or descriptive matter and the genus is monotypic. Van Heurck[5] put the genus under *Xanthiopyxis*.

PLAGIOGRAMMA MARGINATUS Hanna, n. sp.

Plate 20, fig. 8

Valve narrow, elongate, spindle shaped, tapering gradually to the narrowly rounded ends; a space at each end almost twice as long as broad covered with irregularly arranged, very fine beading; central blank area ovate crosswise of the diatom and in the center of a square blank area; sides bordered by a single row of heavy beads joined to the margin; very faint undulations in the silica cross the diatom from one bead to the other; no finer markings seen. Length, 0.060 mm.; width, 0.0087 mm.

Holotype (No. 3035, Mus. Calif. Acad. Sci.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., M. D. M., Fresno County, California; Lower Miocene.

[1] *Lichtdrucktafeln*, pl. 6 (1891), row 4, fig. 16.

[2] *Op. cit.*, pl. 28, row 3, figs. 12, 13.

[3] *Mikrogeologie*, 1854, pl. 35*A*, IX, fig. 4; Ralfs, in Pritchard, *Hist. Brit. Infus.* (4th ed., 1864), p. 865, pl. 8, fig. 44.

[4] *Monatsbericht, Akad. Wiss.* (Berlin), 1845, p. 311; 1846, p. 278.

[5] *Treat. Diat.*, 1896, p. 512.

The species is apparently rare in this deposit. It differs from other known species in having the marginal row of heavy, bead-like structures and by the absence of conspicuous surface markings, other than the faint crosswise undulations mentioned.

PTEROTHECA CARINIFERA Grunow

Plate 20, figs. 9, 10

Pyxilla? carinifera GRUNOW in Van Heurck, Syn. Diat. Belgique, pl. 83, figs. 5, 6; Jutland.

This very common *Pterotheca* has been found in all the localities studied in the Lower Miocene shales north of Coalinga, California (Locs. 894, 995, and 1053, C.A.S.). It is always more slender than *P. danica;* the spine does not end in a sharp point as in *P. aculeifera,* and the upper end of the spine does not branch. Intergradation between these species has not been seen in California formations.

PTEROTHECA DANICA Grunow

Plate 20, fig. 11

Stephanogonia (Pterotheca?) danica GRUNOW in VAN HEURCK, Syn. Diat. Belgique, pl. 83 bis., figs. 7, 8; Mors, Jutland.

This species is much broader and shorter than the otherwise structurally similar *P. carinifera* from the same deposit in Jutland. It is common in the Lower Miocene shales north of Coalinga, Fresno County, California, the species having been seen in material from Locs. 894, 995, and 1053 (C.A.S.).

PYXILLA BARBADENSIS Greville

Plate 20, fig. 12

Pyxilla barbadensis GREVILLE, Trans. Micr. Soc. London, vol. 13, 1865, p. 2, pl. 1, fig. 5.—VAN HEURCK, Treat. Diat., 1896, p. 430, fig. 149.

Greville's figure of this species, reproduced by Van Heurck, is rather crudely drawn; and if allowance be made for this fact, the common form from Lower Miocene shales of Phoenix Canyon near Coalinga, Fresno County, California, can be referred to the species from Barbados. The beading of my material is coarser than he has shown; the tip is a true spine of solid silica; and I have not seen the constriction of the valves in girdle view which is so pronounced in his figure. On examining hurriedly some strewn slides from Barbados in the collection of the Academy, I find only a form which is practically identical with the one here shown.

PYXILLA DUBIA Grunow

Plate 20, fig. 13

Pyxilla? dubia GRUNOW in VAN HEURCK, Syn. Diat. Belgique, pl. 83, figs. 7, 8, Jutland, fossil; pl. 83 bis., fig. 12, Monterey, California [Upper Miocene].

This is a robust *Pyxilla,* usually brown in color on a dry strewn slide. Grunow showed considerable difference in the fine dots between the Jutland and Monterey fossils, but it is doubtful if this is important structurally; otherwise they agree fair-

ly well. The species is not rare in the Lower Miocene material from Loc. 1053 (C.A.S.), 6 miles northwest of Newman, California.

STEPHANOPYXIS APPENDICULATA (Ehrenberg)

Pyxidicula appendiculata EHRENBERG, Monatsber. Akad. Wiss. Berlin, 1844, pp. 85, 264.—EHRENBERG, Mickrog., 1854, pl. 18, fig. 4; Richmond, Virginia.

Stephanopyxis appendiculata (EHRENBERG), SCHMIDT, Atlas Diat., pl. 130, 1888, figs. 18–26, 29, 31, 32, 34, 35.

This is an exceedingly abundant form in the Lower Miocene shales of Phoenix Canyon, near Coalinga, Fresno County, California, as well as at other localities in the same formation. Many variations are present and might be illustrated but it is believed that the classification of the group must be subjected to critical revision before further pictures will aid in its taxonomy.

STEPHANOPYXIS BARBADENSIS (Greville)

Plate 20, fig. 14

Cresswellia barbadensis GREVILLE, Trans. Micr. Soc. London, vol. 13, 1865, p. 3, pl. 1, fig. 11.

Stephanopyxis barbadensis (GREVILLE), SCHMIDT, Atlas, Diat., pl. 130, 1888, figs. 6–10.

The most common species of diatom of this Lower Miocene formation agrees in most respects with the form cited. There is, of course, a great deal of variation, but it is very seldom indeed that a specimen approaches *S. grunowii* in robustness or size of cells. Perhaps in a large series from many formations intergradation of this, *grunowii* and *superba*, could be shown; but certainly my study of separate formations in California does not as yet warrant their union. The greatest variation is in connection with the crown of spines; these may be long and thorn-shaped or short and blunt, even absent in some specimens; and the ring may be close to the margin or far toward the center. The size of the cells likewise is very variable, but they are normally smaller than in *grunowii;* usually they are arranged in rows spaced 60° apart, but I have seen this order broken completely into no regularity whatsoever.

STEPHANOPYXIS SPINOSISSIMA Grunow

Stephanopyxis spinosissima GRUNOW, SCHMIDT, Atlas Diat., pl. 123, 1888, figs. 18–20; Santa Monica, California; Upper Miocene.

Stephanopyxis rudis (GREVILLE), SCHMIDT, Atlas Diat., pl. 164, 1891, fig. 9; Santa Monica, California; Upper Miocene. Not *Cresswellia rudis* GREVILLE, Trans. Micr. Soc. London, vol. 14, 1866, p. 78, pl. 8, fig. 7.

This species is rare in the Lower Miocene shales of Phoenix Canyon, near Coalinga, Fresno County, California. It does not reach the huge size that it does in Upper Miocene strata at Monterey and elsewhere, but otherwise I cannot see that it differs notably. The species is very inconstant in the number, size, and arrangement of the spines; and the central circular area may be large (as in the type) or small, but it appears always to be inclosed with a row of spines. The beading

inside this circle is usually symmetrically arranged in rows meeting at 60°, but diatoms are not rare where this arrangement does not exist; yet otherwise they agree exactly. It appears that, in common with most *Stephanopyxis*, this form is exceedingly variable. Schmidt said that his figures 19 and 20, cited above, were inner plates (*unterschalen*) of *Stictodiscus corona* (Ehr.), but after handling large numbers of them from upper Miocene deposits I cannot agree to this hypothesis.

STICTODISCUS COALINGENSIS Hanna, n. sp.

Plate 20, fig. 15

Triangular, sides gently convex, border narrow; beads heavy, more or less quadrangular, arranged in radial rows in a marginal zone, each row containing four to eight beads; rows separated by characteristic "water lines" of *Stictodiscus*, these lines continuing over the center of the valve as an irregular network; the lines do not vary in strength or width from margin to center; central beads largest, gradually decreasing in size to margin and smallest in the angles. Length of one side, 0.0820 mm.

Holotype (No. 3042, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

The only near relative of this species I have seen is *Stictodiscus harrisonianus* (Norman and Greville)[1] from Barbados, but that form has very sparse beading in the center of the valve. The species is not common in the Lower Miocene shales examined near Coalinga.

STICTODISCUS HARDMANIANUS Greville

Plate 21, figs. 1, 2

Stictodiscus hardmanianus GREVILLE, Trans. Micr. Soc. London, vol. 13, 1865, p. 98, pl. 8, fig. 4; Monterey Miocene.—SCHMIDT, Atlas, Diat., pl. 131, 1888, fig. 5; Oamaru, New Zealand.

Stictodiscus hardmanianus form *minor* SCHMIDT, Atlas, Diat., pl. 74, 1882, fig. 8; Monterey Miocene.

Stictodiscus grovei SCHMIDT, Atlas, Diat., pl. 147, 1890, figs. 5–7; Oamaru, New Zealand.

This common species in California deposits is somewhat less variable than the equally or more common *S. californicus* which is confined to the upper layers of the Miocene shales. In some specimens there is only one row of beads between each two radial grooves or "water lines" while in others there are two. This is hardly sufficient grounds for separation, even varietally as Schmidt has done. The New Zealand fossils do not appear to differ in any noteworthy respect from these California forms, and, in my opinion, the trinomial of Schmidt should be omitted. Depauperate individuals, supposed to be this species, are not uncommon at the three localities (894, 995, 1053) where the Lower Miocene shales have been examined.

[1] *Trans. Micro. Soc. London*, 1861, p. 76, pl. 9, fig. 9 (As *Triceratium*); Schmidt, *Atlas Diat.*, pl. 81 (1885), figs. 8, 9.

TRICERATIUM AMERICANUM Ralfs

Plate 21, fig. 3

Triceratium amblyceros EHRENBERG, BRIGHTWELL, Quar. Jour. Micr. Sci., vol. 1, 1853, p. 250, pl. 4, fig. 14; not of EHRENBERG.

Triceratium americanum RALFS, in PRITCHARD, Hist. Brit. Infus., 4th ed., 1861, p. 855.—SCHMIDT, Atlas Diat., pl. 76, 1882, fig. 28.

This species seems to have been found repeatedly in the deposits of Richmond, Virginia, and Nottingham, Maryland. It has not heretofore been reported from any west American locality, yet it is not uncommon in the Lower Miocene of Phoenix Canyon near Coalinga, Fresno County, California, Loc. 894 (C.A.S.). Schmidt figured two forms, his plate 76, figure 3, being of a specimen from Barbados. It is possible that the coarsely marked form without radial rows of beads in the center should be separated as a distinct species.

TRICERATIUM CASTELLATUM West

Plate 21, fig. 4

Triceratium castellatum WEST, Trans. Micr. Soc. London, vol. 8, 1860, p. 147, pl. 7, fig. 3.—SCHMIDT, Atlas, Diat., pl. 78, 1887, fig. 2; Barbados, "form *major*."

One almost perfect valve of this striking diatom was found at Loc. 1053, 6 miles northwest of Newman, California; Lower Miocene. Various modifications of the species have been named, as for instance, *T. castellatum fractum* Grunow[1] from Oamaru, New Zealand. The California specimen agrees most nearly with Schmidt's figure cited from Barbados, the original type locality of the species.

TRICERATIUM MUCRONATUM Schmidt

Plate 21, fig. 5

Triceratium mucronatum SCHMIDT, Atlas Diat., pl. 111, 1886, figs. 1, 2; "Archangelsk, Russia."

Several specimens of this species were found at Loc. 894, Phoenix Canyon, Lower Miocene. The diatoms are structurally much like *Trinacria*, but in the absence of horns at the corners they would seem best placed elsewhere.

TRICERATIUM VERSICOLOR Brun

Plate 21, fig. 6

Triceratium versicolor typica and *acutangula* SCHMIDT, Atlas, Diat., pl. 166, 1891, figs. 7, 8; fossils from Sendai, Japan.

The treatment necessary to disintegrate the Lower Miocene shales from Phoenix Canyon near Coalinga, California, was so vigorous that these large diatoms were not often recoverable. Enough pieces were found, however, to enable the identification to be made satisfactorily. Both forms named by Schmidt are present, so his trinomials have little taxonomic value. His figures show the beads of the marginal zone very close together; this appearance will be seen in the California specimens if the specimen is slightly out of the focus of the microscope; then

[1] Schmidt, *Atlas Diat.*, pl. 167 (1891), figs. 7–10.

each bead is separated by a space. It seems probable that this condition exists in the Japanese fossils, but the drawings do not show it satisfactorily. At any rate the similarity otherwise is so great that the identification is believed to be correct even though there was this slight difference in the spacing of the beads. There is much greater difference in some cases between two individuals from the same deposit.

TRINACRIA INSIPIENS Witt

Plate 21, fig. 7

Trinacria insipiens WITT, Verh. Russ. Kais. Mineral. Gesell. St. Petersburg, ser. 2, vol. 22, 1886, p. 172, pl. 10, fig. 1; pl. 11, figs. 5, 7, 11; pl. 12, fig. 2; Archangelsk, Simbirsk.—SCHMIDT, Atlas Diat., pl. 97, 1886, fig. 16.

An occasional specimen of this small, coarsely marked species was found in the material from Loc. 995 (C.A.S.), Sec. 19, T. 18 S., R. 15 E., Fresno County, California. They do not appear to differ from those previously reported from the Cretaceous of Russia. I prefer to use Witt's name for these diatoms rather than "*Triceratium pileolus* Ehrenberg"[1]; the latter was applied to a diatom from Antarctic ice floes but was so sketchily drawn that it is very uncertain. Certainly if the cell structure indicated is correct, then all of the fossil forms I have seen are not closely related to it.

TROCHOSIRA TROCHLEA Hanna, n. sp.

Plate 21, figs. 8, 9

The members of the genus *Trochosira* appear to have grown in chains, and the adjacent valves of two individuals were grown together through the formation of an axis of solid silica. In the present species this axis is rather long and slightly twisted; the valve tapers into the axis and the upper surface is conspicuously marked with rather heavy beading, the beads being in radial rows; in girdle view the valves are short; the type specimen, shown herewith, has been broken, one valve with the axis being mounted horizontally; the other valve is shown in vertical position. Diameter, 0.030 mm.

Holotype (No. 3050, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

The genus *Trochosira* was established by Kitton,[2] in 1871 for two species, *mirabilis* and *spinosus*[3] from the fossil deposit of Mors, Jutland. Van Heurck[4] placed the group in *Stephanopyxis*, but Schmidt[5] considered the group distinct, and, it would seem, with sufficient reason. No species of *Stephanopyxis* begins to approach the form of these organisms. They are closely related to some forms which have been referred to *Skeletonema* but differ widely from the typical members of that group. As, for instance, cf. *Skeletonema utriculosum* Brun from Japan in

[1] *Mikrog.*, 1854, pl. 35*A*, group 21, fig. 17.

[2] *Jour. Quekett Micr. Club*, vol. 2 (1871), p. 170.

[3] *Op. cit.*, pl. 14, figs. 7–9.

[4] *Treat. Diat.*, 1896, pp. 434–35.

[5] *Atlas Diat.*, pl. 176 (1892), figs. 55 (*mirabilis*), 56 (*spinosa*); pl. 180 (1892), figs. 48 (*mirabilis*), 49 (*spinosa*).

Schmidt, *Atlas Diat.*, pl. 180, 1892, figs. 27–30; and *Skeletonema barbadense* Greville[1] the type species of the genus. The forms from Jutland are shown with spines, and no mention is made of beading. Our form does not bear a trace of spines.

XANTHIOPYXIS ACROLOPHA Forti

Plate 21, figs. 10, 11

Xanthiopyxis acrolopha FORTI, Nuova Notarisia, vol. 23, 1912, p. 84.—TEMPERE and PERAGALLO, Diat. du Monde Enteir, ed. 2, 1915, p. 331.—FORTI, Contribuzioni Diatomologische; Atti de Reale Ist. Veneto, Sci. Lett. Arti, vol. 72, part 2, 1913, p. 1556 (22), pl. 2, figs. 22, 24, 27, 28, 30–37.

This interesting species, common in the Miocene deposits of Italy, is not subject to as much variation in the Lower Miocene shales of Phoenix Canyon near Coalinga, Fresno County, California, as at the type locality. There is very little deviation from the forms figured herewith. The species is characterized by the central depressed hyaline area. Intergradation with *X. cingulata* or *X. oblonga* apparently does not exist, although in outline the three are similar.

XANTHIOPYXIS OBLONGA Ehrenberg

Xanthiopyxis oblonga EHRENBERG, Mikrogeologie, 1854, pl. 33, group 17, fig. 17; "Rappahannock, Virginia."—CLEVE, Jour. Quekett Micr. Club, ser. 2, vol. 2, 1885, p. 175, pl. 13, fig. 18; Brun Tegel (Marl), Moravia.—HANNA and GRANT, Proc. Calif. Acad. Sci., 4th ser., vol. 15, 1926, p. 170, pl. 21, fig. 11; Maria Madre Island, Mexico; Upper Miocene.

This species is not rare in the collections from Phoenix Canyon and Sec. 19, T. 18 S., R. 15 E., Fresno County, California; the specimens appear to differ in no important particular from those taken in Miocene deposits elsewhere. It is less common in the formation being considered than *X. acrolopha.*

XANTHIOPYXIS SPECTICULARIS Hanna, n. sp.

Plate 17, fig. 10

Composed of two flat circles joined together by a hyaline isthmus, concave on each side; border heavy, but narrow and with heavy spines scattered along, here and there; surface of circles marked with numerous faint, short hair-like lines which extend roughly in fan shape from the junction of isthmus and circle; also on the surface there are a very few short but heavy bristlelike spines. Length, 0.0562 mm.; width, 0.0253 mm.

Holotype (No. 3006, Mus. Calif. Acad. Sci.) from Loc. 894, Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

The markings of this diatom are faint and require the use of lenses of high aperture for good resolution. I have seen no similar species except *X. panduraeformis* Pantocsek[2] from the Tertiary of Hungary; the latter is heavily marked and no hyaline area at the isthmus.

[1] *Trans. Micr. Soc. London*, vol. 13, N. S. (1865), p. 43, pl. 5, fig. 1.

[2] *Beit. Kennt. Foss. Bacill. Ungarns*, part 1 (1886), p. 43, pl. 29, fig. 297.

EXPLANATION OF PLATES

PLATE 17

FIG. 1.—*Actinodiscus californicus* Hanna, n. sp., ×560. Holotype (No. 3000, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.0635 mm.

2.—*Actinoptychus oamaruensis* Grunow, ×560. Plesiotype (No. 3001, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.080 mm.

3.—*Asterolampra punctifera* Grove, ×1500. Plesiotype (No. 3002, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.032 mm.

4.—*Arachnoidiscus indicus* Ehrenberg, ×750. Plesiotype (No. 3003, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.050 mm.

5.—*Arachnoidiscus manni* Hanna and Grant, ×280. Plesiotype (No. 3004, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.1360 mm.

6.—*Biddulphia tuomeyii* (Bailey), ×500. Plesiotype (No. 3005, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0772 mm.; width, 0.0233 mm.

7.—*Cocconeis notabilis* Schmidt, ×1280. Plesiotype (No. 3007, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0474 mm.; width, 0.0328 mm.

8.—*Coscinodiscus excentricus* Ehrenberg, ×560. Plesiotype (No. 3008, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.0644 mm.

9.—*Coscinodiscus fasciculatus* Schmidt, ×560. Plesiotype (No. 3009, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.050 mm.

10.—*Xanthiopyxis spectacularis* Hanna, n. sp., ×1075. Holotype (No. 3006, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0562; width, 0.0253 mm.

PLATE 18

FIG. 1.—*Coscinodiscus oculus-iridis* EHRENBERG, ×250. Plesiotype (No. 3010, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.210 mm.

2.—*Coscinodiscus radiatus* Ehrenberg, ×480. Plesiotype (No. 3011, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.0960 mm.

3.—*Coscinodiscus tuberculatus* Greville, ×700. Plesiotype (No. 3012, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.051 mm.

4.—*Dicladia trinodis* Hanna, n. sp., ×1000. Holotype (No. 3013, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length, 0.0372 mm.

5.—*Dicladia trinodis* Hanna, n. sp. Sectional view.

6.—*Entopyla frickei* Hanna, n. sp. Holotype (No. 3014, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length, 0.1580 mm.; width, 0.0182 mm.

7.—*Entopyla frickei* Hanna, n. sp., ×465. Detail of sculpture.

8.—*Hemiaulus claviger* Schmidt, ×400. Plesiotype (No. 3053, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.10 mm.; width, 0.044 mm. Sectional view shown at *a*.

9.—*Hemiaulus polymorphus* Grunow, ×1000. Plesiotype (No. 3015, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Width, 0.0284 mm.; height, 0.030 mm.

10.—*Hemiaulus polymorphus* Grunow; end view, ×500. Plesiotype (No. 3016, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0638 mm.; width, 0.0180 mm.

11.—*Hercotheca mammillaris* Ehrenberg, ×750. Plesiotype (No. 3019, C.A.S.) from Loc. 1053, 6 miles northwest of Newman, California; Lower Miocene. Length, 0.060 mm.; width, 0.0347 mm.

PLATE 19

FIG. 1.—*Biddulphia tuomeyii* (Bailey), ×875. Plesiotype (No. 3017, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length, 0.0580 mm.; height, 0.030 mm.

2.—*Biddulphia tuomeyii* (Bailey), ×875. Plesiotype (No. 3018, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene.

3.—*Liradiscus circularis* Hanna, n. sp., ×685. Holotype (No. 3020, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.060 mm.

4–6.—*Liradiscus ovalis* Greville, ×500. Plesiotypes (Nos. 3021–3023, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length (fig. 4), 0.060 mm.; width, 0.0451 mm.

7.—*Biddulphia petrolia* Hanna, n. sp. ×1300. Holotype (No. 3024, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0284 mm.; width, 0.0198 mm.

8.—*Melosira caliginosa* Hanna, n. sp., ×950. Holotype (No. 3025, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.0413 mm.

9, 10.—*Melosira lolia* Hanna, n. sp., ×950. Syntypes (Nos. 3026, 3027, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Diam. (exclusive of spines), 0.0389 mm.

PLATE 20

FIG. 1.—*Melosira sulcata* (Ehrenberg), ×950. Plesiotype (No. 3028, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.0378 mm.

2.—*Navicula eudoxia* Schmidt, ×750. Plesiotype (No. 3029, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0752 mm.; width, 0.0269 mm.

3.—*Navicula lyra* Ehrenberg, ×770. Plesiotype (No. 3030, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length, 0.080 mm.; width, 0.0375 mm.

4.—*Navicula nitescens* Gregory, ×500. Plesiotype (No. 3031, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length, 0.060 mm.; width, 0.0253 mm.

5.—*Navicula tolmani* Hanna, n. sp., ×750. Holotype (No. 3032, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0580 mm.; width, 0.0215 mm.

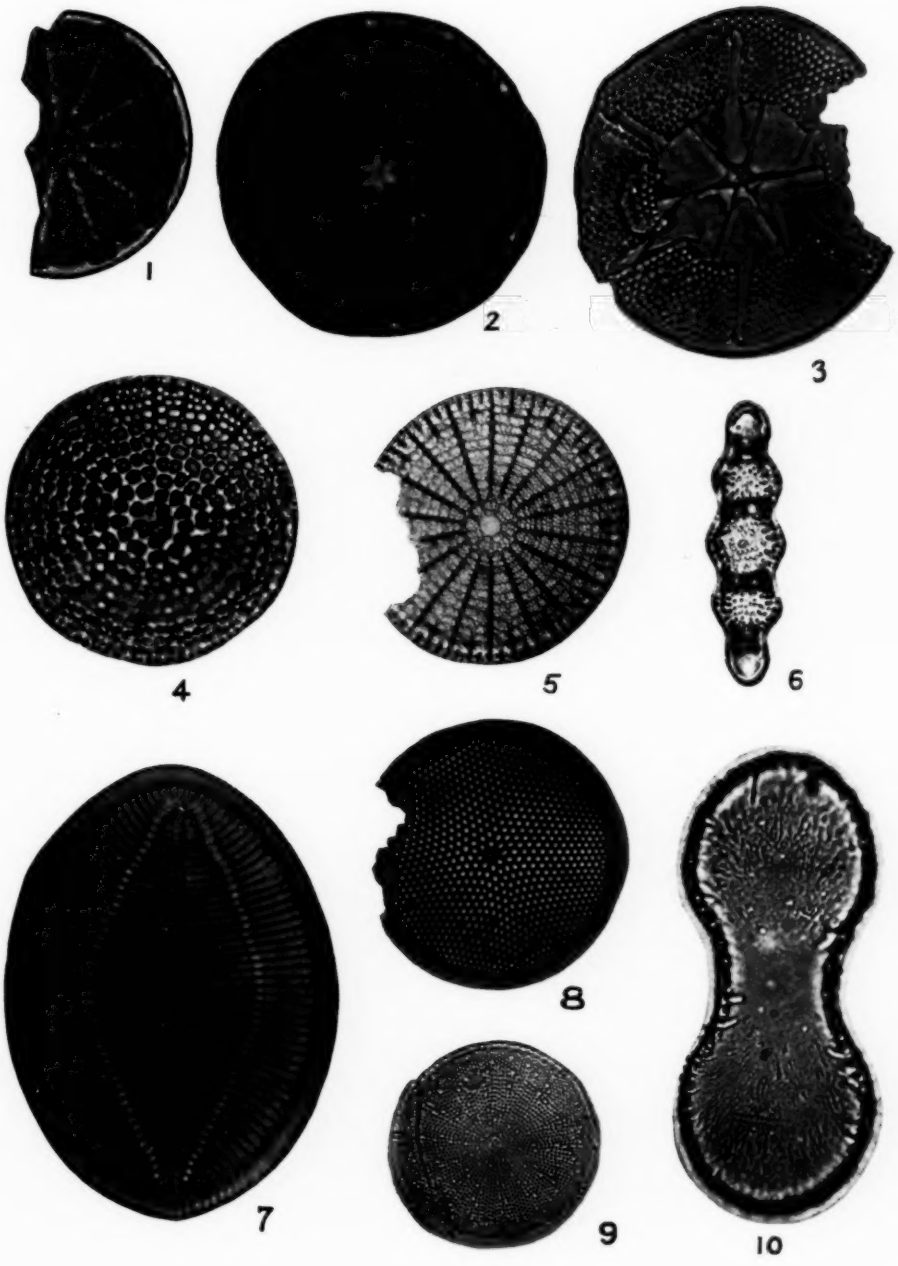
6, 7.—*Omphalotheca californica* Hanna, n. sp., ×1350. Syntypes (Nos. 3033, 3034, C.A.S.) from Loc. 1053, 6 miles northwest of Newman, California; Lower Miocene. Diam., 0.0291 mm.

8.—*Plagiogramma marginatus* Hanna, n. sp., ×950. Holotype (No. 3035, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length, 0.060 mm.; width, 0.0087 mm.

9, 10.—*Pterotheca carinifera* Grunow, ×375. Plesiotypes (Nos. 3036, 3037, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Fig. 9, length, 0.0750 mm.; width, 0.0252 mm. Fig. 10, length, 0.0639 mm.; width, 0.010 mm.

11.—*Pterotheca danica* Grunow, ×375. Plesiotype (No. 3038, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.070 mm.; width, 0.0413 mm.

12.—*Pyxilla barbadensis* Greville, ×375. Plesiotype (No. 3039, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.0477 mm.; diam., 0.0277 mm.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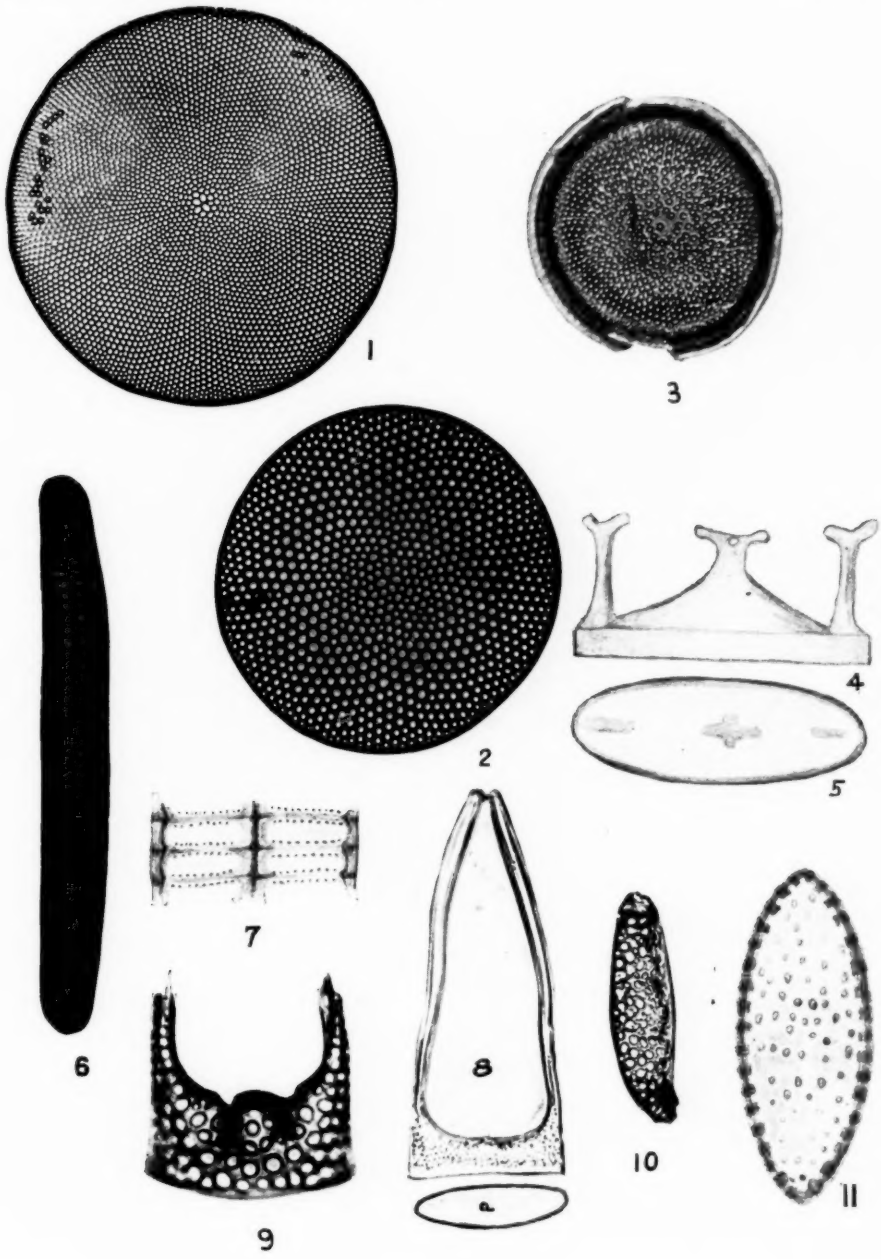
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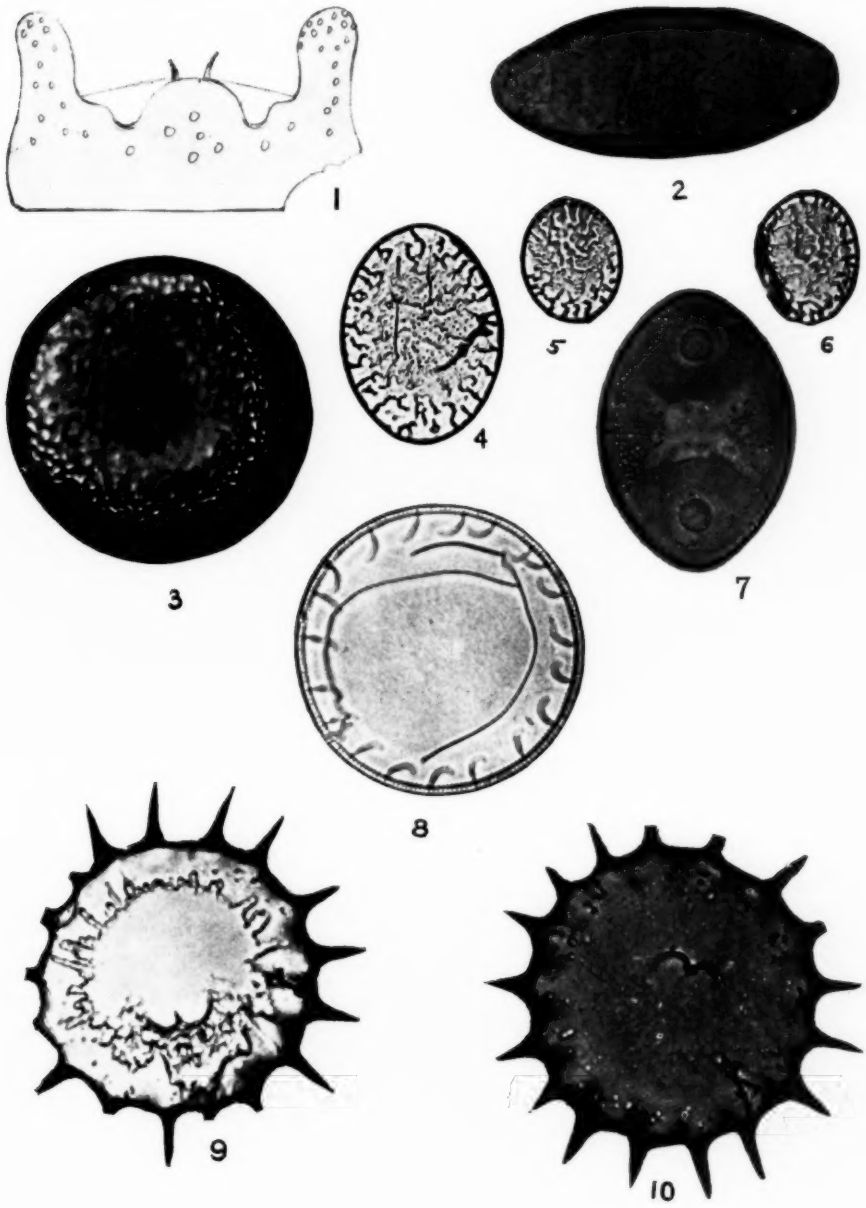
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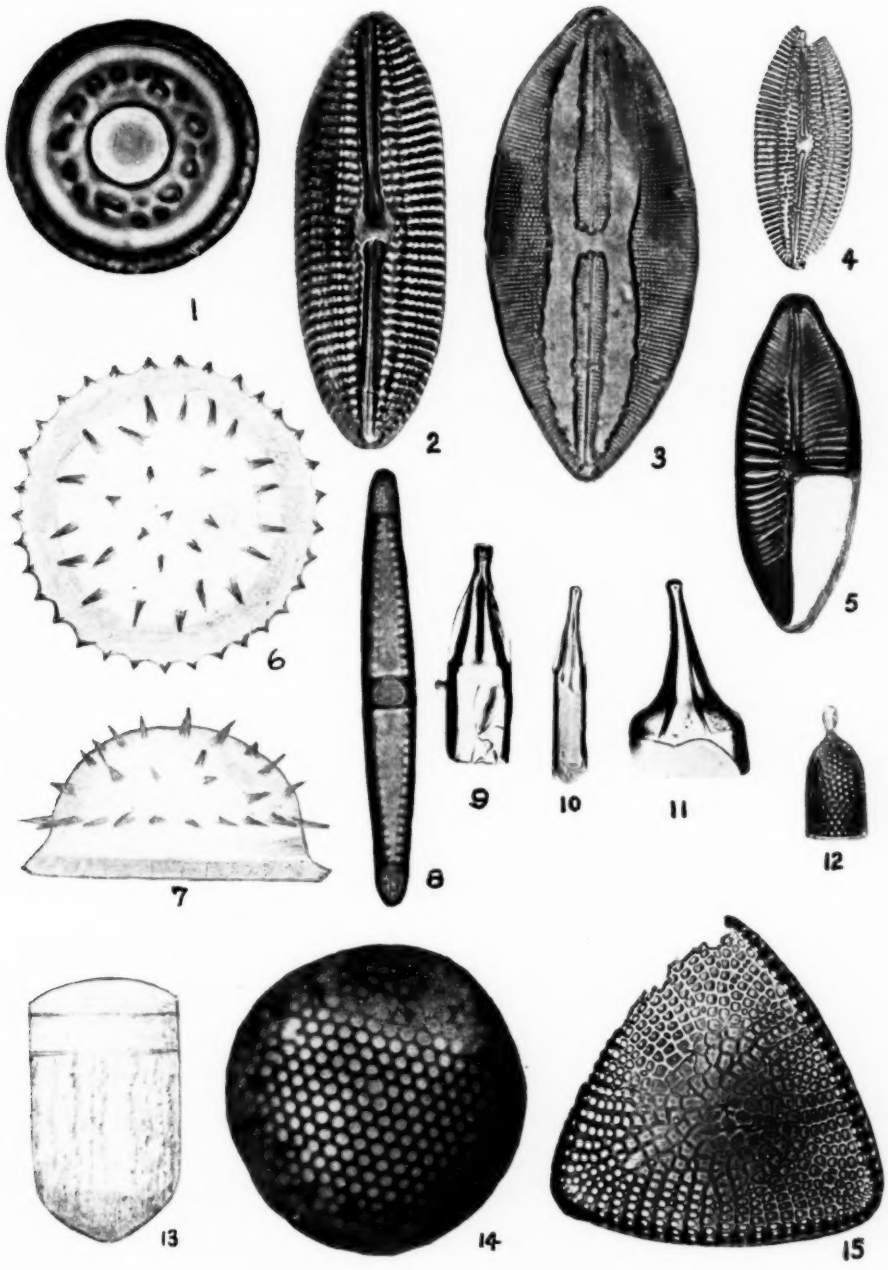
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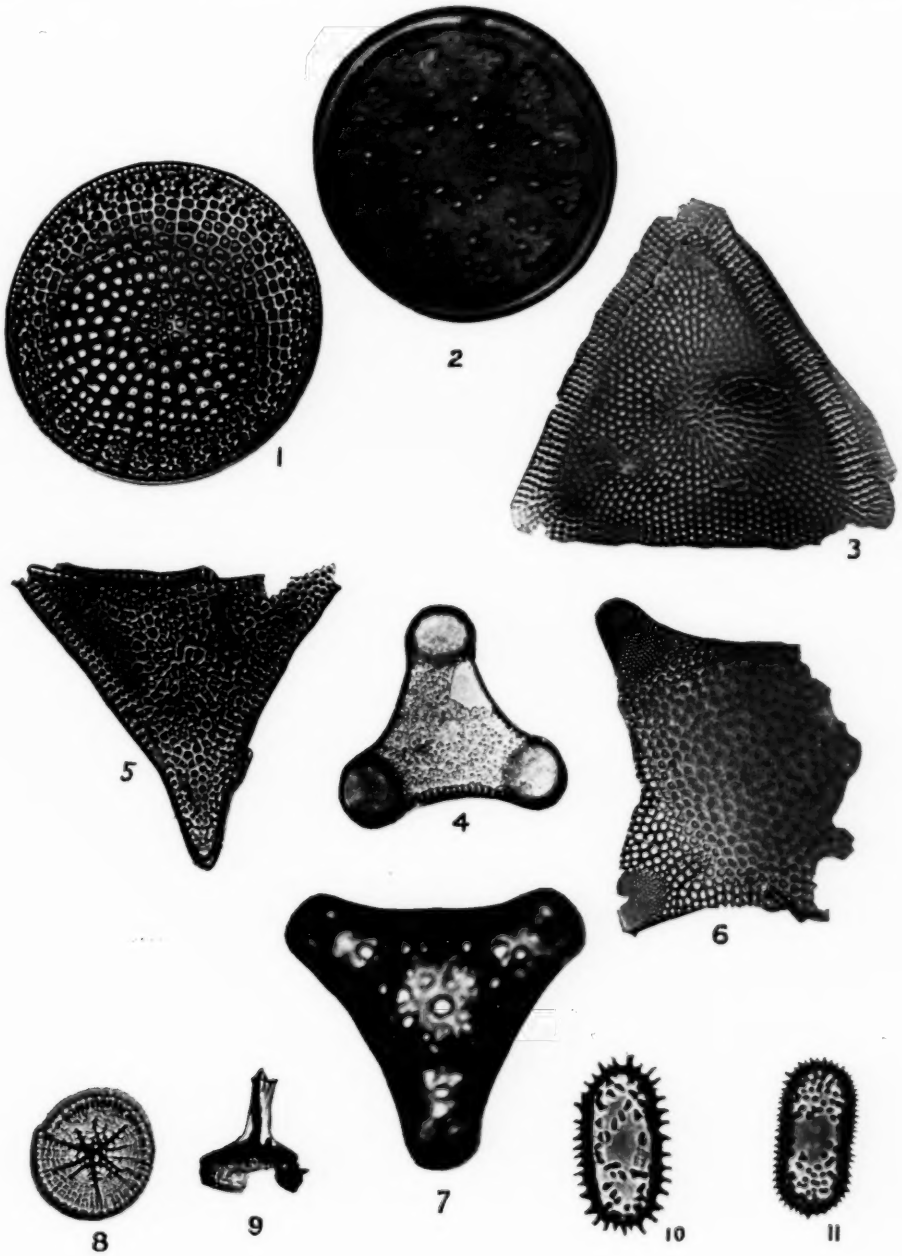
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13.—*Pyxilla dubia* Grunow, ×750. Plesiotype (No. 3040, C.A.S.) from Loc. 1053, 6 miles northwest of Newman, California; Lower Miocene. Length, 0.0470 mm.; width, 0.0275 mm.

14.—*Stephanopyxis barbadensis* Greville, ×700. Plesiotype (No. 3041, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Diam., 0.0560 mm.

15.—*Stictodiscus coalingensis* Hanna, n. sp., ×430. Holotype (No. 3042, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length of one side, 0.0820 mm.

PLATE 21

FIG. 1.—*Stictodiscus hardmanianus* Greville, ×750. Plesiotype (No. 3043, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Diam., 0.0551 mm.

2.—*Stictodiscus hardmanianus* Greville; depauperate, ×1350. Plesiotype (No. 3044, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Diam., 0.030 mm.

3.—*Triceratium americanum* Ralfs, ×650. Plesiotype, No. 3045, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length of one side, 0.0780 mm.

4.—*Triceratium castellatum* West, ×575. Plesiotype (No. 3046, C.A.S.) from Loc. 1053, 6 miles northwest of Newman, California; Lower Miocene. Length of one side, 0.0535 mm.

5.—*Triceratium mucronatum* Schmidt, ×550. Plesiotype (No. 3047, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length of one side, 0.0860 mm.

6.—*Triceratium versicolor* Brun, ×475. Plesiotype (No. 3048, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length of one side, 0.0954 mm.

7.—*Trinacria insipiens* Witt, ×1350. Plesiotype (No. 3049, C.A.S.) from Loc. 995, Sec. 19, T. 18 S., R. 15 E., Fresno County, California; Lower Miocene. Length of one side, 0.030 mm.

8, 9.—*Trochosira trochlea* Hanna, n. sp., ×600. Holotype (No. 3050, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, Fresno County, California; Lower Miocene.

10, 11.—*Xanthiopyxis acrolopha* Forti, ×400. Plesiotypes (Nos. 3051, 3052, C.A.S.) from Phoenix Canyon, 7 miles north of Coalinga, California; Lower Miocene. Length, 0.040 mm.; width, 0.020 mm.; specimens same size.

A GROUP OF FORAMINIFERA FROM THE DORNICK HILLS FORMATION OF THE ARDMORE BASIN[1]

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A very good method of using microfaunas for correlation work is to study characteristic foraminiferal groups of the minor subdivisions created by geologists and macropaleontologists.

The change in a faunal group which occurs from bed to bed due to the dropping out of some species and the beginning of new ones is often very marked. The change is so abrupt in many instances that the species and even the genera of one group are not found in another group although the strata from which they come are closely related in age.

For checking and determining the age of horizons in localities where little or no geological information is available such groups from known type localities are valuable.

Single species vary considerably between localities, so they must be used with caution. Familiarity with the associated species in a group helps the worker in correlating though the local variation and evolutionary changes in individual species have not been studied.

Laterally persistent groups which are confined to limited vertical zones and which consist of the same associated species wherever found, are common in the Carboniferous formations.

The rather startling changes in the microfaunas from some of the Carboniferous formations were caused not only by a break in the continuity of deposition but also by the intervening barren zones which were deposited under conditions unfavorable for the microfossils. Rapid variation in the sediments and depths at which they were deposited, with variation in the corresponding pressures and temperatures, caused the barren zones, the faunas not being able to adapt themselves to the new conditions. Later, new groups were formed, the barren zones being the dividing line between the groups.

Such a distinctive group of Foraminifera from the Dornick Hills formation of the Ardmore Basin is herein described. This fauna was obtained from the rather pure shales exposed in Sec. 30, T. 3 S., R. 2 E., in Carter County Oklahoma—shales which lie between the Jolliff and Otterville limestones. It has been found in several localities in the Ardmore Basin, in outcrops in Johnson and Atoka counties in Oklahoma and in wells drilled in west Texas. The fauna consists of arenaceous species most of which seem to be new.

[1] This paper was prepared under the guidance of Dr. J. A. Cushman and published by permission of the Sun Oil Company, Dr. F. H. Lahee, chief geologist.

A study of the morphology of these species adds to the value of the group as a marker. The tests are composed of sand grains, or sand grains and sponge spicules, cemented with material of iron composition. This is in direct contrast to the tests of species from the Upper Pennsylvanian, which are generally composed of calcareous grains cemented with lime.

The chemical examination was carried out with hydrochloric acid for lime and potassium thiocyanate for iron. It was found that the sediments in which the forms occur also contained iron but that the forms from the Upper Pennsylvanian sediments had not absorbed the iron. It was inferred, then, that the species from the Lower Pennsylvanian did not absorb the iron from the sediments after deposition, but had used a cement of iron composition in building their tests. The Upper Pennsylvanian species effervesce in hydrochloric acid, while those from the Lower Pennsylvanian do not.

The following classification with descriptions and drawings illustrate the individual characteristics of the species making up the group.

Family HYPERAMMINIDAE

Genus HYPERAMMINA H. B. Brady, 1878

HYPERAMMINA GRACILIS Waters, n. sp.

Plate 22, figs. 4, 5

Test elongate, slender, nearly straight; consisting of a fusiform prolocum and elongate subcylindrical, somewhat compressed second chamber with the diameter less than that of the proloculum; wall finely arenaceous with a large proportion of cement, smoothly finished; aperture oval, central, terminal; color, brown or white.

Length, up to 3 mm.; diameter of proloculum, 0.7 mm.; diameter of tubular chamber, 0.2 mm.; thickness of wall, 0.3 mm.; diameter of opening, 0.14 mm.

Holotype (U. S. National Museum, No. 71700) from SE. $\frac{1}{4}$, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

This species differs from the following in the shape of the test and the lack of constrictions in the tubular chamber.

HYPERAMMINA GRACILIS Waters, n. sp., var. RUGOSA Waters n. var.

Plate 22, figs. 6 *a*, *b*

Variety differing from the typical form in the different shape of the proloculum, which in the variety is flattened and asymmetrical; in the second tubular chamber, which is constricted but not definitely divided; and in the wall, which has much less cement, the surface somewhat roughened.

Length, 1.5 mm.; diameter of proloculum, 0.4 mm.; diameter of tube, 0.4 mm.; thickness of wall, 0.08 mm.; diameter of opening, 0.14 mm.

Holotype (U. S. National Museum, No. 71701) from SE. $\frac{1}{4}$, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

This variety is similar in many ways to *Hyperammina distorta* Cushman (*Bull.*

104, U. S. Nat. Mus., part 1 [1918], p. 78). The recent species has a similar shaped proloculum and constricted tubular chamber showing that these characters are not entirely due to conditions of fossilization, as might be inferred.

Family REOPHACIDAE

Genus NODOSINELLA H. B. Brady, 1876

NODOSINELLA LAHEEII Waters, n. sp.

Plate 22, figs. 8 *a*, *b*

Test large, tapering, straight or slightly curved; chambers usually six in number, slightly overlapping, increasing rapidly in size as added, the last-formed one in the adult very much longer in proportion than the others; sutures strongly depressed; wall coarsely arenaceous, of sand and sponge spicules with a small proportion of cement; aperture small, circular, central and terminal; color, brown or white.

Length of type specimen, 2.8 mm.; diameter of chambers, 0.22 mm., 0.32 mm., 0.47 mm., 0.57 mm., 0.72 mm., 1.00 mm.; length of chambers, 0.13 mm., 0.21 mm., 0.31 mm., 0.43 mm., 0.50 mm., 1.15 mm.

Holotype (U. S. National Museum, No. 71702) from SE. ¼, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

The relative increase in size of the chambers with the very large terminal chamber will distinguish this species from those associated with it.

NODOSINELLA BREVIS Waters, n. sp.

Plate 22, figs. 9 *a*, *b*

Test small, slender, nearly straight; chambers usually six or more, slightly overlapping and elongate, increasing very gradually in size as added; sutures distinct but not deeply depressed; wall finely arenaceous with a relatively small proportion of cement, aperture large, circular, central and terminal; color, brown or white.

Length of type specimen, 1.25 mm.; diameter of chambers, 0.12 mm., 0.16 mm., 0.22 mm., 0.22 mm. 0.28 mm., 0.31 mm.; length of chambers, 0.14 mm., 0.14 mm., 0.14 mm., 0.13 mm., 0.30 mm., 0.41 mm.

Holotype (U. S. National Museum, No. 71703) from SE. ¼, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

NODOSINELLA CRASSA Waters, n. sp.

Plate 22, figs. 10 *a*, *c*

Test large, straight, tapering; chambers five or more, inflated, slightly overlapping, increasing uniformly in size as added; sutures strongly depressed; wall coarsely arenaceous, of sand with a small amount of cement, smoothly finished; aperture small, circular, central and terminal; color, white.

Length of type specimen, 2.7 mm.; diameter of chambers, 0.31 mm. (estimated), 0.47 mm., 0.62 mm., 0.81 mm., 0.94 mm.; length of chambers, 0.22 mm. (estimated), 0.30 mm., 0.61 mm., 0.61 mm., 0.80 mm.

Holotype (U. S. National Museum, No. 71704) from SE. ¼, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

Family AMMODISCIDAE

Genus AMMODISCUS Reuss, 1861

AMMODISCUS SEMICONSTRICTUS Waters, n. sp.

Plate 22, figs. 1 *a–d*

Test nearly circular, planispiral, biconcave; proloculum small, ovoid; tubular second chamber oval in transverse section, irregularly constricted, open at the terminal end, about nine coils in the adult test; wall coarsely arenaceous, the sand grains cemented with a small proportion of cement; aperture a circular opening at the end of the tubular chamber; color, white.

Diameter of test, 1 mm.; diameter of tube at aperture, 0.1 mm.; thickness of wall at aperture, 0.03 mm.

Holotype (U. S. National Museum, No. 71705) from SE. ¼, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

This species differs from *Ammodiscus incertus* d'Orbigny in the very marked constrictions of the tubular chamber and the smaller proportion of cement. The wall is proportionately thick as is indicated in figure 1 *d*. In some respects, the species resembles *Trochamminoides* especially in the more definitely constricted specimens.

AMMODISCUS SEMICONSTRICTUS Waters, n. sp., var. REGULARIS Waters, n. var.

Plate 22, figs. 2 *a*, *b*

Variety differing from the typical form of the species in the smaller size, fewer coils, and especially in the lack of the constrictions so characteristic of the typical form of the species.

Diameter of test, 0.8 mm.; diameter of tube at terminal end, 0.07 mm.

Holotype (U. S. National Museum, No. 71706) from SE. ¼, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

Genus AMMOLAGENA Eimer and Fickert, 1895

AMMOLAGENA CONTORTA Waters, n. sp.

Plate 22, fig. 4

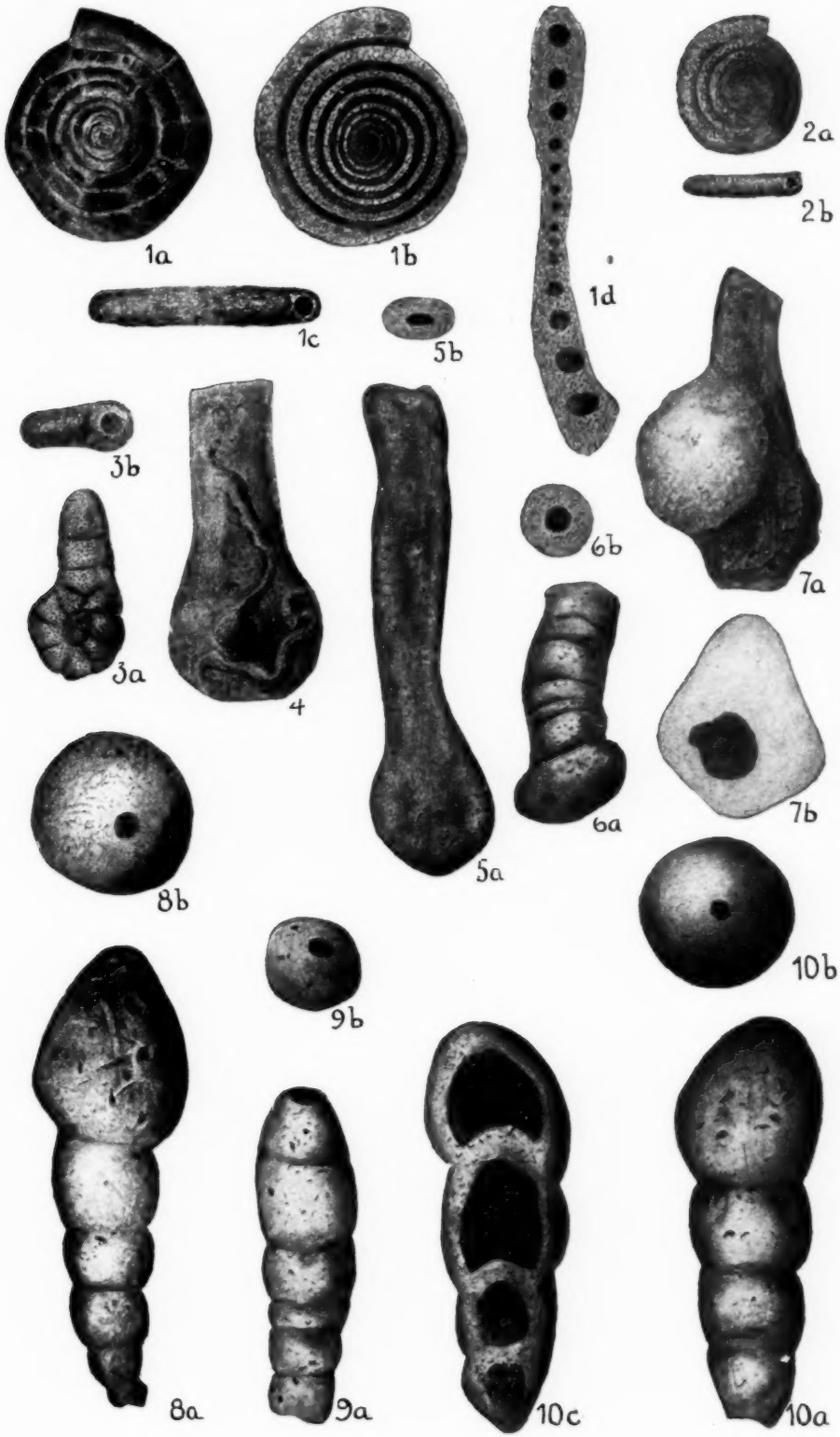
Test slender, attached, consisting of a small, oval proloculum and very elongate, contorted, attached, tubular second chamber; wall very finely arenaceous with a large proportion of reddish-brown cement; aperture formed by the open end of the tubular chamber.

Diameter of tubular chamber, 0.1 mm.

Holotype (U. S. National Museum, No. 71707) from SE. ¼, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

This is a very slender species with the tubular chamber very long and slender, but possessing the same reddish-brown color of recent specimens.

This species differs from the other two found associated with it in the nearly straight sides, more elongate and less inflated chambers, and less depressed sutures, as well as in the material of which the test itself is made.


1a
1b
1c
1d
2a
2b
3a
3b
4
5a
5b
6a
6b
7a
7b
8a
8b
9a
9b
10a
10b
10c

Genus AMMOBACULITES Cushman, 1910

AMMOBACULITES MINUTA Waters, n. sp.

Plate 22, figs. 3 *a*, *b*

Test small, planispiral in the early portion, later rectilinear, periphery rounded, very slightly umbilicate, chambers in the early coiled portion with eight usually making up the coil, three or four in the rectilinear series, distinct, very slightly inflated; sutures distinct, only slightly depressed; wall finely arenaceous, the sand grains with but little cement, exterior smoothly finished; aperture small, circular, terminal, with evidence of a slight neck; color white.

Diameter of coiled portion, 0.3 mm.; diameter of final chamber, 0.2 mm.; length, 0.6 mm.

Holotype (U. S. National Museum, No. 71708) from SE. $\frac{1}{4}$, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

Family PLACOPSILINIDAE

Genus STACHEIA H. B. Brady, 1876

STACHEIA SUBGLOBOSA Waters, n. sp.

Plate 22, figs. 7 *a*, *b*

Test attached, usually to *Hyperammina*, planoconvex, attached by the flattened side; chambers apparently labyrinthic, wall finely arenaceous with a few sponge spicules and small proportion of cement; color, white.

Holotype (U. S. National Museum, No. 71709) from SE $\frac{1}{4}$, Sec. 30, T. 3 S., R. 2 E., Carter County, Oklahoma.

EXPLANATION OF PLATE

PLATE 22

FIGS. 1 *a–d*.—*Ammodiscus semiconstrictus* Waters, n. sp. *a*, side view; *b*, section; *c*, peripheral view; *d*, transverse section.

2 *a*, *b*.—*Ammodiscus semiconstrictus* Waters, n. sp., var. *regularis* Waters, n. var. *a*, side view; *b*, peripheral view.

3 *a*, *b*.—*Ammobaculites minuta* Waters, n. sp. *a*, side view; *b*, end view.

4, 5.—*Hyperammina gracilis* Waters, n. sp. Fig. 4 with *Ammolagena contorta* Waters, n. sp., attached to the surface. 4 *a*, front view; *b*, section.

6 *a*, *b*.—*Hyperammina gracilis* Waters, n. sp., var. *rugosa* Waters, n. var. *a*, front view; *b*, section.

7 *a*, *b*.—*Stacheia subglobosa* Waters, n. sp. *a*, side view; *b*, section.

8 *a*, *b*.—*Nodosinella laheeii* Waters, n. sp. *a*, front view; *b*, end view.

9 *a*, *b*.—*Nodosinella brevis* Waters, n. sp. *a*, front view; *b*, end view.

10 *a*, *b*.—*Nodosinella crassa* Waters, n. sp. *a*, front view; *b*, end view; *c*, section.

THE USE OF EVOLUTIONARY CHANGES IN GEOLOGIC CORRELATION[1]

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ABSTRACT

Progressive changes in faunas are indexes of time. The record of the development of keels in Cristellarias, the evolution of Pseudotextularia from Guembelina, and Pulvinulina from Globigerina, are useful in making age determinations. Detailed studies of evolutionary changes make closer correlations possible.

The geologist who is confronted with the problem of making correlations from field to field and from well to well in the quickest possible time must use all tools which are available. He is not engaged in research for research's sake, but he feels the need of becoming just as efficient in his work as his colleague in pure science. Comparisons of faunas as groups are sufficient for much of the everyday work, but the writer believes that closer studies of species, and especially of the trends of evolution of definite groups, are exceedingly valuable both to individuals and to companies. A certain amount of system and mechanical arrangement for filing data is necessary, but the subject is not a mechanical one which fits into a few definite pigeon holes—rather, it is a history of the development of numerous interfingering and diverging races, an outline of their advances, culminations, and disappearances.

We have learned that genera make progress along definite lines. It is true that simple types persist, but it is equally true that certain humble forms gradually change to more complex and specialized types, often with increasing rapidity. Other forms make progress along entirely different lines at the same time and may diverge by acquiring new characters or even approach in character and form other lines distantly related to them. One can note aberrant forms which are disconcerting to the person who is trying to learn the tendency of a group. But change takes place, and if one can learn the direction of this change one can use the fauna to better advantage than if only an occasional species is known. Many of these changes in geologic history were world-wide; others were provincial. The development of multiserial types in Guembelinas was world-wide. The fauna of the Paris Basin in some respects was provincial. In correlating from one continent to another, one must know something of world-wide trend; and in correlating from one field to another, one should be familiar with the history of the life in the sedimentary basin embracing them.

In the Paleozoic is found a more simple assemblage of Foraminifera than in the

[1] Published by permission of the chief geologist of the Pure Oil Company. Read before the Association at the Tulsa meeting, April, 1927. Manuscript received by the editor, April, 1927.

Comanchean—not necessarily simple, merely simpler than their descendants. In some parts arenaceous forms were more abundant than calcareous types. *Ammodiscus*, *Trochammina*, *Textularia*, *Haplophragmium*, and *Bigenerina* lived. *Archaediscus*, *Bradyina*, *Cribrospira*, and *Cribrostomum* may have been limited to the Carboniferous. *Endothyra* and *Fusulina* were abundant in parts of the Paleozoic and were limited to that system. Thus we note that the specialized species did not reappear in the Mesozoic but left the simpler forms to make the nucleus from which later faunas grew. In the Comanchean, forms are found which gave rise to individuals of the Gulf series. For example, some of the simple Cristellarias, Guembelinas, Anomalinas, and Pulvinulinas gave rise to similar and much more specialized types in the Gulf series. The gap caused by unconformity is considerable but there are evidences of the evolution which took place and of the Comanchean ancestors. In the lower part of the Gulf series, forms are noted which gave rise to more varied forms of the upper Gulf series. The simple Cristellarias and Guembelinas of the lower giving rise to the specialized types of the upper. Likewise simple Cretaceous foraminifera produced varied and abundant specialized types. By Jackson time the unobtrusive Uvigerinas of the Austin and Taylor formations, or their near relatives, had grown to be large, decorated specimens characteristic of the Upper Eocene.

The sum total of a later fauna is not necessarily more specialized than the preceding one. Decorated specialized types may die, leaving later species to be persistent common forms. Eocene Guembelinas do not appear to be as specialized as those of the Cretaceous which preceded them, for bizarre Guembelinas disappeared. The branches of a genus advance along definite lines; the rise, the culmination, and the disappearance of those are of value to the paleontologist who is not merely content with identifying species.

There are paleontologists who believe that certain Globigerinas became Pulvinulinas. I use *Pulvinulina* as the old word which includes Cushman's *Globotruncana* and *Globorotalia*. If a *Globigerina* were to gradually compress its chambers, to slowly flatten the dorsal side, to partly close and move the aperture toward the periphery, and to add "fringes" along the edges and at the suture lines, it could easily be imagined to be *Pulvinulina caniculata*, one of the group popularly termed "rosetta." The compression of chambers can be noted. The flattening of the dorsal side is apparent. The gradual assuming of the rosette pattern has been observed in our laboratory. The shift in aperture is the one important change which remains to be seen, but there is some evidence pointing to this movement. It is noticeable that some Globigerinas have a great similarity to certain Pulvinulinas. This may be a case of parallel evolution of different genera, or it may be the developing of one branch of a genus from a branch of another genus. It does not necessarily follow that all Pulvinulinas were so derived, even if the rosette kinds were derived from Globigerinas. Few indeed, would suggest that our classification supposes that all members of a genus were derived from the same common ancestor.

Many Cristellarias of the Cretaceous developed keels and a few of them developed keels of marked thinness and of considerable width. The acquisition of the specialized keel is noted as a development and not as a sudden mutation. It is a product of slow evolution well shown by the changes from Eagle Ford to Navarro. This character is less noticeable in the Texas Eocene, although it does exist to a certain extent. The growth of large, smooth and beaded bosses and an increase in thickness and rotundity are other lines of *Cristellaria* development shown both in the Cretaceous and in the Eocene. Some Cristellarias took unto themselves a fashion of uncoiling into Hemicristellarias, and no one can draw the exact line of demarcation. It is much the same question as the old one, "What is the difference between an animal and a plant?" That is easy until you find a plant which functions as an animal and an animal which appears to function as a plant. The Hemicristellarias developed from Cristellarias, and yet there is a stage in youth where one is similar to the other. Certain young Hemicristellarias in the Comanchean can scarcely be distinguished from certain Cristellarias, but there is a distinct difference between the adult specimens of the two genera.

Guembelinas may or may not have come from Textularias. Be that as it may, we believe that *Guembelina* is a valid genus and that a majority of the calcareous forms can be distinguished from their arenaceous cousins. Guembelinas were not always content with their lot, and during the Cretaceous some ornamented themselves with striations while others added extra rows of chambers and the more elite kept up with both fashions. Great decorating and multiplying of chambers was followed by an extinction of the extreme types, and only the conservatives were left to carry their racial history into post-Cretaceous time.

It might be well to mention some of the factors which have contributed to the changes just noted. Sedimentary conditions doubtless have a wide influence on types of organisms, on their abundance and on the nature of evolution. If the abundance of fossils is an index to favorable or unfavorable circumstances, one would suspect that Austin (chalk) time was more favorable than Eagle Ford in the Gulf Embayment. There is an abundance of forms in many parts of the calcareous and non-calcareous Eagle Ford shale, but it is nothing like the abundance in certain parts of the Austin where the chalk is made of little else than fossil fragments. Similarly, the Taylor marl is also favorable in many places, as well as the succeeding Navarro, for both of these formations contain abundant faunas in many localities and at many horizons. It would be interesting to know why the Taylor and Navarro shales contain more fossils than the Eagle Ford shale. It may have been due to a shift in shore line, an increase in the lime content, a difference in temperature, an increase or decrease in depth, a difference in mud in suspension, or some other sedimentary condition or set of conditions favorable for life or for the preservation of shells. We have observed that, at least in places, in the syncline in east Texas the lithology is greatly different from the lithology of the same formations in wells nearer the outcrop to the west. The faunas are meager and different from the abundant ones at the outcrop or in wells on the west flank of the syncline. A

change in sedimentation toward the optimum conditions would be likely to cause an increase in the number of individuals, and a change away from the optimum conditions would cause a decrease in abundance.

The incoming of a foreign fauna has often suddenly changed the character of the life in a basin. The migrations of South American species to the New York region gave rise to new characters in the Devonian of that area,[1] and the migration of Silutian trilobites from Bohemia gave a special type to the silurian of Arkansas.[2] In a similar way the incoming of outside influences might have aided in the change which we notice took place among the microfaunas of the Cretaceous of Texas. This could explain part of the increase in numbers and the addition of some new characters. I do not believe that the increase in specialization was entirely due to these outside influences. Not all of the development was due to immigration for not all of the new characters came in without warning, as would have been the case if they had been due entirely to a new fauna or faunas. Some of the changes took place gradually. It has been noted that keels of increasing width and thinness can be noted in Cristellarias before the rise of this character. We have also seen that striations in Guembelinas are noted before heavily marked forms became common. A tendency toward multiserial arrangement is noted long before this character became general.

Organisms grow, specialize, reproduce, and die; and in much the same way groups of organisms increase, develop, and form branches specializing in different characters. These various branches reach their culminations and become extinct in their own times. This evolution is partly due to power inherent within the group, a characteristic force operating in the organic kingdom; the tendency for the group to go through a cycle similar to the cycle of the individual. After the direction of progress has become definite, a certain momentum of evolution is acquired which will take the group through a particular cycle, if strong outside influences do not modify the course. Often there is a tendency for forms to become more abundant, as well as a tendency for a change in character; and these changes may begin slowly but approach the culmination with great acceleration. Some of this development may be due to this evolutionary tendency, and the increase in numbers and the rate of specialization may be determined partly by the proximity to the spectacular phase in development.

Our laboratory has been making a series of studies of the evolution of certain groups of Foraminifera believing that progressive changes are valuable indices of time. We also believe that a knowledge of the characters in different formations and in different parts of the formations, without special regard to specific determinations, is of great value. We believe that often it is possible to place new forms in such lines of development and use them for correlation. This might be called the method of interpolation.

Of course we must take cognizance of the fact that the presence of primitive

[1] Chamberlin and Salisbury, *Geology*, vol. 2 (1905), pp. 472–73.

[2] G. Van Ingen, *School Mines Quar. Jour.*, vol. 23 (1902), p. 35.

forms does not exclude the presence of advanced forms. The absence of advanced types in one or two samples does not indicate that they are not present at that horizon elsewhere or even nearby. Too often we take a 6-foot core, break off a 3-inch sample, choose an integral cubic inch to wash and have a tenth of that fragment left as finely divided material, and do well to examine half of this. No wonder we do not find a representative fauna in one sample. Although a little off the subject, it might not be amiss to say that our best success in taking samples, both in the field and from the core, is to select many little fragments from different parts to make a composite, rather than to take one large piece or an integral sample. One composite sample from a place 10 feet square at the Falls of the Brazos near Marlin, Texas, yielded thirty-five to forty species which were abundant, and many more could have been counted if one had gone into detail or had sought the rarer kinds. No one fragment had half of the number. Other composite samples taken a few feet away yielded other forms, but the one sample had a representative fauna from that horizon. The character of a fauna should not be determined from an integral cubic inch of material. Unconformities are useful in making correlations, but they are hindrances to the study of the development of faunas. There is a marked unconformity between the Comanchean and the Gulf series, and a very great unconformity between the Gulf series of Texas and the Eocene. One must search elsewhere if one is to piece together these breaks in the history. Within the Gulf series there is an unconformity between the Eagle Ford and the Austin which is noted both in field and laboratory work. Another unconformity appears to exist between the Taylor and Navarro, as is revealed in the ranges of microfaunal forms and differences in sedimentation. Stephenson has mentioned this unconformity and also another one between the Austin chalk and Taylor marl in southwest Texas.[1] In spite of these hindrances, one can piece together much of the history of Cretaceous faunal groups.

A study of the changes in micro- as well as in mega-faunas seems to be worth while amid the hustle of the daily routine, and certainly it is of great use in tackling new problems. In our experience it is valuable in saving time at periods when hours are most valuable.

[1] Lloyd W. Stephenson, *Bull. Amer. Assoc. Pet. Geol.* vol. 2, no. 1 (1927), pp. 1–17.

CHANGING CHARACTERS IN SOME TEXAS SPECIES OF GUEMBELINA[1]

N. L. THOMAS AND E. M. RICE

ABSTRACT

There was an increase in ornamentation and in the development of multiserial characters in the Guembelinas of the Gulf Embayment of Texas during the Cretaceous. These changes are distinctive and useful for correlation.

While paleontologists know that regular and progressive changes take place in the character and appearance of faunas as time goes on, too often the ones in commercial work are forced merely to see a species here and a species there without fully realizing the continuity of the advance or the stages under which the changes take place. An attempt is made in this paper to note some of the changes which have taken place in a part of one fauna during a definite period of time. The Guembelinas of the Gulf series of Texas are used because they illustrate the principles in a clear fashion and because they are useful in stratigraphy. A study of their changes is important in making Cretaceous correlations. We will merely indicate the dominant features of the Guembelinas of the Eagle Ford, Austin, Taylor, and Navarro formations. It might be well to define the genus *Guembelina* since many continue to use the term *Textularia*. Galloway[2] described Egger's[3] type as follows: "Test free, minute, tapering, biserial; chambers globular, not closely appressed, wall calcareous, hyaline, finely perforate; aperture semi-lunar, at the base of the last chamber. A calcareous isomorph of *Textularia*."

The plate is not for the purpose of giving detailed lines of progress for that would require the illustration of a large number of specimens; nor is it intended to represent any particular species which is described in literature. It is supposed to show some of the prevailing types in their respective formations, and the reader can piece together the details of the manner in which progressions took place, or preferably he can look for it in his own laboratory.

While some parts of the Eagle Ford contain relatively few microfossils, there are many horizons which have prolific faunas; and of these faunas Guembelinas make up a considerable part. The prevailing forms are simple compared with those of the same genus in the upper part of the Cretaceous. Globular chambers are characteristic of many Eagle Ford Guembelinas; and a marked lack of specialized decoration, aside from granulations and perforations, is typical. Multiserian species appear to be absent. These features which characterize most of the Guem-

[1] Read before the Association, Tulsa meeting, March 25, 1927, by permission of the chief geologist of the Pure Oil Company. Manuscript received by the editor, May 19, 1927.

[2] J. J. Galloway, "A Manual of the Families and Genera of Foraminifera" (unpublished), p. 94.

[3] Joseph Georg Egger, *Abhandl. Math. Phys. Cl. K. Bay. Akad. Wiss.*, vol. 21 abth. 1 (1899), p. 31, pl. 41, fig. 43.

belinas of the Eagle Ford are features which also characterize the Guembelinas of long geologic range. They are the kinds which lived in Comanchean time, persisted through the Cretaceous, and continued to live in Eocene and later ages. These are the ones which gave rise to the more varied and prolific Guembelinas as well as the ones which continued after the specialized and prolific species declined. Whether the specialization of the Guembelinas found in the later Cretaceous formations was the result of the environmental changes or the incoming of new species is not well known, but certainly it was not a sudden mutation. The biserial tests did not become the advanced multiserial kind in a single change, for there was an indication of multiserial characters before *Pseudotextularia* became common. Plain tests did not become highly ornamented in one step, but alteration took place in progressive stages and, we are beginning to believe, in many stages. Progress was not uniform; sometimes it was slow, and sometimes it was rapid. In this paper it would take too long to note the stages, but we can indicate the trend and show the characters in the different formations. Those of the Eagle Ford have been indicated.

During early Austin time the simple forms continued to be prevalent, and as a whole the Guembelinas of this formation did not tend to specialize to any marked degree, although in later Austin time there was considerable advance, a beginning of the changes which took place during Taylor and Navarro sedimentation. The fauna might be called an intermediate one. For example there was a development in several directions, an acquiring of more varied characters, a tendency toward more rapid increase in the size of chambers, and a beginning of striations.

Taylor and Pecan Gap formations contain many new species, although simple Guembelinas persist. Some of the simple ones expanded their chambers rapidly, others tended to become more nearly square in cross-section, others became multiserial in character, and still others took on striations, while the striated types of the Austin became even more decorated. These embellished fossils are distinct and are apparently well separated from their modest cousins. Yet it is possible to lay out a series of Guembelinas ranging from the kinds which prevailed in Eagle Ford time to the most striated kind of the Taylor, at least a series complete enough to convince one that it represents the evolution which has taken place in that particular direction. Similarly one can make a series leading into the multiserian types—into the genus *Pseudotextularia* itself. Furthermore a certain acceleration can be noted in the rate of change.

Simple Guembelinas persisted during Navarro sedimentation; but more intricate, more specialized, and more decorated forms were abundant. It was there that *Guembelina* specialization reached its climax in the northern Gulf Embayment of Texas. Among the advanced types one should note those which tended to become square in cross-section and striated in manner of decoration and those which became striate and multiserial. It is possible that these multiserian forms did not evolve from the slightly decorated and undecorated multiserian types which came before, but sprang from some true, striated *Guembelina*. It is likely that there were

several general lines of evolution trending in different directions but taking place at the same time, and it seems that there is at least one noticeable case of parallel evolution.

The plate indicates most of the general characters which we have been discussing. The first three figures may give an adequate picture of the prevailing Guembelinas below the Austin chalk, but those representing the other three formations are not sufficient in number to truly illustrate the many varied characters of their times. The plate shows the existence of the simple forms through the Cretaceous, the development of varied characters, the acquisition of striations, and the addition of extra chambers. In our work we have used these as separate species and have

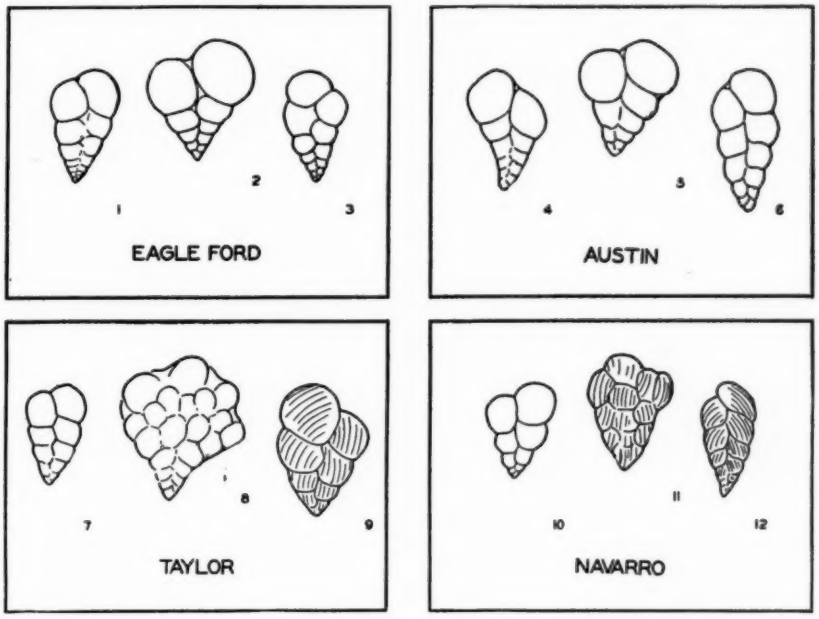


FIG. 1

found that *Guembelina globulosa* may be divided into several varieties which are of some stratigraphic significance. Furthermore, we have reason to believe that no. 8, *Planoglobulina acervulinoides* (Egger), came from a simple, probably unstriated Guembelina; and in this connection it is interesting to note that Cushman has found an intermediate stage in which *Planoglobulina acervulinoides* (Egger) was derived from *Pseudotextularia varians* Rzehak.[1] Among the striated forms we do not believe that *fracticosa* was a descendant of *acervulinoides*, even though *acervulinoides* occurs in the Taylor and *fracticosa* in the Navarro. It seems more likely that *fracticosa* is a descendant of a striated *Guembelina*, and there is some evidence

[1] Joseph Augustine Cushman, *Contributions from the Cushman Laboratory for Foraminiferal Research*, vol. 3, part 1 (March, 1927), p. 60, pl. 20, figs. 4 and 5.

to support this belief. Certain striated Guembelinas indicate a tendency toward the multiserial characters in *fracticosa* in adult states.

Dr. Galloway has kindly checked the following determinations of some of the figures on the plate (magnification 50 ×):

EXPLANATION OF TEXT FIGURE

No. 2.—*Guembelina* cf. *globulosa* (Woodward and Thomas, not Ehrenberg).
4.—*Guembelina globifera* (Reuss).
6.—*Guembelina concinna* Reuss?.
8.—*Planoglobulina acervulinoides* (Egger).
9.—*Guembelina decurrens* (Chapman).
11.—*Pseudotextularia fracticosa* (Egger).
12.—*Guembelina striata* (Reuss).

We shall make no attempt to explain the dearth of Guembelinas in later formations but shall merely note that the Eocene lacks the abundance, the specialization, and the decoration which are so common in the formations of the Upper Cretaceous. The humble species survive, but the decorated types do not degenerate into plainer kinds and survive. There is some indication of degeneration in the decorated types in the Cretaceous, but this degeneration leads to extinction and not to a quieter trend of long life. Thus again we see one of the laws of biology illustrated, and this illustration is of great benefit for one making determinations and correlations by the use of faunas from well samples and cores.

CLARIFICATION OF OIL-DISCOLORED BROMOFORM[1]

MARCUS A. HANNA
Houston, Texas

Probably the liquid most commonly used by sedimentologists for gravity separations is bromoform. Its uses have been described in numerous papers[2] and need not be discussed here. Merely one point will be mentioned. Bromoform is an excellent solvent for petroleum oils. Where gravity separations are made of samples carrying even only small amounts of petroleum, the bromoform used often becomes very brown. In fact, the bromoform used on samples which have been completely washed with hot water is often too badly discolored for satisfactory results, if the original sample contained much petroleum. This condition, of course, is most often encountered by sedimentologists working with petroleum-bearing horizons, the samples from which must be examined, although the bromoform used does become discolored. Since bromoform is somewhat expensive, it is not desirable to discard it merely because of discoloration, if its utilization is economically possible.

Several methods of decoloration can be employed, but for the average laboratory worker, where speed is desired but equipment often lacking, the writer has found that fuller's earth gives quite satisfactory results. Although the decoloration is not complete, since any color due to free bromine remains, the product is more desirable than the oil-discolored bromoform. The writer allows five pounds or so of the oil-discolored bromoform to accumulate before decolorizing with fuller's earth. After decoloration has taken place, the bromoform is filtered. The fuller's earth which remains in the filter paper is washed with alcohol to remove the remaining bromoform. The alcohol and dissolved bromoform is then washed in water.[3]

[1] Published with permission of the Gulf Production Company.

[2] See C. S. Ross, "Preparation of Sedimentary Materials for Study," *Econ. Geol.*, vol. 21, no. 5 (August, 1926); also, Marcus A. Hanna, "Separation of Fossils and Other Light Materials by Means of Heavy Liquids," *Econ. Geol.*, vol. 22, no. 1 (January-February, 1927).

[3] C. S. Ross, *op. cit.*, pp. 457–58.

SOME CHARACTERISTIC MEXICAN FOSSIL FORAMINIFERA

JOSEPH A. CUSHMAN

While the Tertiary and Cretaceous foraminiferal faunas of Mexico are very rich, there are numerous species that are either particularly abundant or especially striking in their appearance that will serve to identify the principal formations. The species that have been figured and described from Mexico are scattered in the literature, and this paper brings many of them together. Only a few characteristic species are taken from each genus, sometimes but one; whereas many of the genera are represented by many species often difficult to distinguish. The species given here are all distinctive and not liable to be confused with any others. The Miocene and Oligocene are so much more easily distinguished that no attempt is made here to give species of those series. Of the Alazan species, numerous characteristic ones are given. From the Tantoyuca where the fauna is much smaller, specimens are particularly abundant of certain species, a number of the most common ones being figured here. Many of the Velasco species have already been figured, but a few of the more common or striking ones are included. The fauna in the Upper Mendez is a very characteristic one and represented by comparatively few species, but those often occur in great numbers.

I am indebted for permission to publish the data herein to the Aguila Company, including the species collected by Dr. T. Wayland Vaughan and for many of the figures, and to the Marland Company for the material collected by Earl Oliver, Earl A. Trager, and myself.

Many of the Mexican species of both the Cretaceous and Tertiary occur also in equivalent formations of Texas and the general Gulf Coastal Plain of the United States as well as in the Tertiary of the West Coast.

It may be possible to publish more detailed faunas of the different formations from the large collections placed in my hands from various sources. This short paper will however give a general series of characteristic species with figures for many of them.

No attempt is made to give complete synonymy, which is not needed in a paper of this sort. A reference to the original publication and to other references to Mexican material is usually all that is given. A few short generic descriptions where recent changes have been adopted are made for clearness.

Family TEXTULARIIDAE

Subfamily TEXTULARIINAE

Genus TEXTULARIA Defrance, 1824

TEXTULARIA DIBOLLENSIS Cushman and Applin

Plate 23, fig. 1

Textularia dibollensis DUMBLE (nomen nudum), Bull. Amer. Assoc. Petr. Geol., vol. 8, 1924, p. 443.—CUSHMAN AND APPLIN, *op. cit.*, vol. 10, 1926, p. 165, pl. 6, figs. 12–14.

The types of this species are from 4 miles east of Diboll, Angelina County Texas. The species has a broad range in the Upper Eocene of the Gulf Coastal Plain of the United States and occurs in the Alazan of Mexico, but the Mexican specimens are slightly larger than the types.

Maximum length, 0.8 mm.; maximum breadth, 0.43 mm.

Specimens were collected by Dr. T. Wayland Vaughan on the Rio Tuxpan, south side, just above Agua Nacida, Vera Cruz, Mexico.

TEXTULARIA SUBHAUERII Cushman

Plate 23, fig. 2

Textularia subhauerii CUSHMAN, U. S. Geol. Survey Prof. Paper 129, 1922, pp. 89, 126, pl. 14, figs. 2 *a*, *b*; Prof. Paper 133, 1923, p. 16.

Specimens similar to that figured occur in the Alazan clay on Rio Vinasco, right bank, 1.35 km. S. of crossing of Buena Vista–Vinasco Road. It is a large, stout species, usually tapering strongly in the microspheric form, but less so in the megalospheric.

TEXTULARIA HOCKLEYENSIS Cushman and Applin

Plate 23, fig. 3

Textularia hockleyensis DUMBLE (nomen nudum), Bull. Amer. Assoc. Petr. Geol., vol. 8, 1924, p. 443.—CUSHMAN AND APPLIN, *op. cit.*, vol. 10, 1926, p. 164, pl. 6, figs. 3–6.

There is a large species of *Textularia* in the Tantoyuca formation of Mexico that very strongly resembles *T. hockleyensis* described from the Upper Eocene of Texas. It also is related to *T. byramensis* Cushman from the Lower Oligocene of Mississippi.

Genus VULVULINA d'Orbigny, 1826

Nautilus (in part) BATSCH, Conch. Seesands, 1791, pl. 4, figs. 13 *a–e*.

Vulvulina D'ORBIGNY (type *V. capreolus* d'Orbigny), Ann. Sci. Nat., vol. 7, 1826, p. 264.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 24.

Schizophora REUSS, Sitz. Akad. Wiss. Wien, vol. 44, 1861, p. 373.

Venilina GÜMBEL, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 10, 1868 (1870), p. 648.

Bigenerina of authors (in part)

Test much compressed throughout, earliest stages in the microspheric form planispiral, then biserial; later chambers in the adult uniserial; wall finely arenaceous, with much cement; aperture elongate, simple, terminal.

VULVULINA SPINOSA Cushman

Plate 28, fig. 4

Vulvulina spinosa CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 2, 1927, p. 111, pl. 23, fig. 1.

This species is peculiar in the angular projections, the roughened surface and the general direction of the sides nearly parallel.

The species is fairly common in some parts of the Alazan clay. The types are from Rio Buena Vista, just south of crossing of Alazan to Moyutla Road, Vera Cruz, Mexico, collected by Dr. Vaughan.

The species apparently occurs also in Trinidad and on the west coast of South America.

Family VERNEUILINIDAE

Genus GAUDRYINA d'Orbigny, 1839

GAUDRYINA VELASCOENSIS Cushman

Plate 28, fig. 2

Gaudryina velascoensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 20, pl. 3, figs. 7 *a, b;* Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 587, pl. 16, fig. 9.

This is one of the peculiar species of the Velasco shale and may be distinguished by the early triserial portion, later nearly quadrangular, with the sides in the young having fine longitudinal striations.

Genus TRITAXILINA Cushman, 1911

TRITAXILINA MEXICANA Cushman

Tritaxilina mexicana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 3, 1925, p. 64, pl. 10, fig. 4.

This is one of the characteristic species limited to horizons in the Alazan clay. The types are from Rio Buena Vista, just south of crossing of Alazan to Moyutla road, Vera Cruz, Mexico, collected by Dr. Vaughan.

Genus CLAVULINA d'Orbigny, 1826

CLAVULINA TRILATERA Cushman

Plate 28, fig. 1

Clavulina trilatera CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 588, pl. 17, fig. 2.

This is one of the characteristic species of the Velasco shale with flattened or concave sides, smoothly finished but coarsely arenaceous wall, and terminal circular aperture with a slight neck.

CLAVULINA CLAVATA Cushman

Plate 28, fig. 3

Clavulina clavata CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 589, pl. 17, fig. 4.

In certain horizons of the Velasco shale this is one of the characteristic species. Its vertical range is strictly limited. The club-shaped form with the uniserial chambers smaller in diameter than the early triserial portion will distinguish it from all other Mexican species.

Family SILICINIDAE

Genus RZEHAKINA Cushman, 1927

Silicina RZEHAK (not BORNEMANN), Annal. K. K. Naturhist. Hofmuseums, vol. 10, 1895, p. 214.

Rzehakina CUSHMAN (type *R. epigona* (Rzehak)), Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 31.

Test finely arenaceous, usually siliceous; wall thin; planispiral, compressed, but the chambers forming a half coil, the test longer than broad, median portion depressed; aperture somewhat narrow, constricted.

RZEHAKINA EPIGONA (Rzehak)

Plate 23, fig. 4

Silicina epigona RZEHAK, Annal. K. K. Naturhist. Hofmuseums, vol. 10, 1895, p. 214, pl. 6, fig. 1.

Rzehakina epigona CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, pl. 6, fig. 6.

This species with its coiled compressed form, arenaceous test, and elongate aperture occurs as a characteristic species in the Velasco shale. The central portion is depressed.

Family MILIOLIDAE

Genus MASSILINA Schlumberger, 1893

MASSILINA JACKSONENSIS Cushman, n. sp.

Plate 23, figs. 5, 6

Test broadly oval or elliptical, much compressed, periphery subacute, apertural end slightly projecting; early chambers quinqueloculine, later ones in a single plane and spiroloculine; sutures distinct, slightly depressed; wall beautifully ornamented by a series of punctae, nearly circular, arranged in longitudinally curved rows parallel to the sutures and often in somewhat definite curved diagonal lines across the chamber; apertural end with a short neck but without a distinct lip.

Length, up to 1.40 mm.; breadth, 1 mm.; thickness, 0.20 mm.

Holotype (U. S. Nat. Mus., No. 369305) from Alazan clay, Rio Buena Vista, Vera Cruz, Mexico, collected by Dr. T. Wayland Vaughan. The species is abundant in the Upper Eocene, Jackson at Jackson, Mississippi.

The early stages are occasionally found represented by young individuals and strongly resemble *Quinqueloculina*. Some of the larger megalospheric forms do not attain the full adult characters as in figure 6, but occur with the others and have the same ornamentation. They remotely resemble some of the forms referred by authors to *Quinqueloculina prisca* d'Orbigny, but they are sharply angled and their association with *Massilina jacksonensis* reveals their true relationship.

Family LAGENIDAE

Genus ROBULUS Montfort, 1808

The generic name *Robulus*, with the many other names given by Montfort, is in doubt until the satisfactory determination of Lamarck's species *Lenticulites rotulata*. If the type of that species shows that it is a cristellarian form, it may be that names will have to be again shifted. Until such time as this study is made, *Robulus* may be used for those species in which there is a secondary opening in addition to the usual radiate aperture. It may be noted, however, that this is a variable character and the secondary aperture becomes merged with the radiate opening above it and often disapperars in more compressed individuals in the same species. The cristellarian forms are noted for their variability, and indeed the whole family shows greater plasticity than almost any other of the foraminifera. The following species may be placed under *Robulus*.

ROBULUS CULTRATUS Montfort

Plate 23, fig. 7

Robulus cultratus MONTFORT, Conch. Syst., vol. 1, 1808, p. 215, 54th genre.

This species is distinguished by the triangular apertural face with an elongate elliptical secondary opening in addition to the radiate one, the periphery of the test usually having a broad keel. The keel is very variable and may be greatly reduced or wanting.

This form figured is common in the Alazan shales of Mexico.

ROBULUS MEXICANUS (Cushman)

Plate 23, fig. 8

Cristellaria mexicana CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 9, 1925, p. 299, pl. 7, figs. 1, 2.

An examination of the apertural characters of this species shows that it should be placed under *Robulus*. It is one of the abundant and characteristic species of the Tantoyuca formation of Mexico. The types were from the Moctezuma River, but it occurs widely distributed in the Tantoyuca.

ROBULUS cf. VAUGHANI (Cushman) (?)

Plate 23, fig. 10

The form figured occurs in considerable numbers in the Alazan clays of Mexico and resembles in many ways a species described as *Cristellaria vaughani* from the Culebra formation of the Panama Canal Zone. The aperture of the Mexican species, however, is not so projecting.

ROBULUS BUDENSIS (Hantken)

Plate 23, fig. 11

Robulina budensis HANTKEN, A. magy. Kir. földt. int. evkönyve, vol. 4, 1875 (1876), p. 49, pl. 14, fig. 13.

The specimen figured here is typical of a species that occurs rather commonly at certain zones in the Alazan clays. It is apparently identical with Hantken's species from the *Clavulina- Szaboi* beds of Hungary.

Genus CRISTELLARIA Lamarck, 1812

The remarks already made under *Robulus* will apply to *Cristellaria* as to its generic use. Until such time as mooted points in regard to the nomenclature of this group can be settled by reference to the type specimens, it seems wise to continue the use of *Cristellaria* for those forms at least that are not definitely robuline.

CRISTELLARIA CONVERGENS Bornemann

Plate 23, fig. 12

Cristellaria convergens BORNEMANN, Zeitschr. deutsch. geol. Ges., vol. 7, 1855, p. 327, pl. 13, figs. 16, 17.

In the Alazan there occur numerous specimens of *Cristellaria* in which the apertural face is rounded and nearly continuous with the peripheral margin. They may be referred to Bornemann's species.

CRISTELLARIA ALAZANENSIS Cushman, n. sp.

Plate 23, fig. 13

Test biserially symmetrical, close-coiled except in the adult where the last-formed chambers tend to uncoil slightly, about eight chambers in the coil, periphery rounded and at the angle of each chamber a projecting blunt spine, sutures slightly limbate, only slightly depressed; wall smooth, aperture radiate.

Length, up to 1.5 mm.

Holotype (U. S. Nat. Mus., No. 369306) from Alazan clay on Rio Buena Vista, 0.5 km. S. 25° E. from Tumbadero Hacienda House, Vera Cruz, Mexico, collected by Dr. T. Wayland Vaughan. Dr. Vaughan also collected it on the Rio Buena Vista, 9.8 kms. in a straight line upstream from Tumbadero, and on the Rio Buena Vista, right bank, 5.5 km. S. E. of Portreo del Llano and across the river from Llano Grande well.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA JACKSONENSIS (Cushman and Applin)

Plate 24, fig. 12

Cristellaria jacksonensis CUSHMAN AND APPLIN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 172, pl. 8, fig. 10.

In the Alazan occur numerous specimens apparently identical with the species described from the Jackson of Texas. The figured specimen is an unusually long one, the later chambers showing the characteristic inflated form, and the early portion with the periphery acute.

Genus DENTALINA d'Orbigny, 1826

DENTALINA MULTILINEATA Bornemann

Plate 24, figs. 7, 8

Dentalina multilineata BORNEMANN, Zeitschr. deutsch. geol. Ges., vol. 7, 1855, p. 325, pl. 13, fig. 12.—SHERBORN AND CHAPMAN, Jour. Roy. Micr. Soc., 1886, p. 751, pl. 15, fig. 14.

There are fragments in the Alazan clays that seem identical with this species as described and figured by Bornemann from Germany and by Sherborn and Chap-

man from the London clay. Specimens occur frequently in the Alazan clays of Mexico. It was collected by Dr. Vaughan at stations on the Rio Buena Vista.

DENTALINA COCOAENSIS (Cushman)

Plate 24, fig. 14

Nodosaria cocoaensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 3, 1925, p. 66, pl. 10, figs. 5, 6.

Nodosaria sp., CUSHMAN AND APPLIN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 170, pl. 7, fig. 17.

Test elongate, very slender, slightly curved, gradually tapering from the acute or spinose initial end, early portions with the sides straight, toward the apertural end with the chambers slightly inflated; chambers numerous, in the microspheric form with as many as twenty, in the early portion only slightly longer than broad but in the adult as much as two and one-half to three times as long as broad in the last-formed ones; sutures very distinct, of clear shell material; wall very smooth, slightly polished in well-preserved specimens; apertural end produced. Length, up to 2.25 mm.; maximum breadth, 0.20 mm.

This species was originally described from the Upper Eocene of Alabama. It is also known from the Upper Eocene of Mississippi, Georgia, and South Carolina. In the Alazan clays it occurs at type locality of the Alazan on the Buena Vista collected by Dr. Vaughan, as well as near the junction of the Rio Pantepec and Rio Tuxpan.

NODOSARIA EWALDI Reuss

Plate 24, figs. 1, 2

Nodosaria ewaldi REUSS, Zeitschr. deutsch. geol. Ges., vol. 3, 1851, p. 58, pl. 3, fig. 2.

Owing to the weakness developed at the junction of the elongate chambers, complete specimens of this species are very rare. The usual specimens unless very careful methods are used consist of but one or two chambers. Some of the chambers become very elongate in the adult. The megalospheric proloculum is shown in figure 3. The species is known from numerous localities in the Tertiary of Europe. It also occurs in the Eocene (Jackson) of the Coastal Plain of the United States. It was collected in Mexico by Dr. Vaughan at many localities in the Alazan clays.

NODOSARIA JACKSONENSIS Cushman and Applin

Plate 24, fig. 3

Nodosaria jacksonensis CUSHMAN AND APPLIN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 170, pl. 7, figs. 14–16.

Test elongate, tapering, straight or gently curved, initial end rounded with one to several spines, sides lobulate throughout, more strongly so in later growth; chambers subglobular, fairly numerous, inflated, length and breadth about equal in the earlier chambers but in later ones often becoming more elongate; sutures distinct, depressed, of clear shell material; surface smooth, usually polished; aper-

ture with a cylindrical neck. Maximum length, 2.50 mm.; maximum breadth, 0.35 mm.

The types of this species are from the Upper Eocene of Texas. It is found in the Upper Eocene of the Coastal Plain region eastward in Mississippi, Alabama, Georgia, and South Carolina. In the Alazan clays it occurs at many of the stations from which Dr. Vaughan collected.

NODOSARIA ACULEATA d'Orbigny

Plate 24, fig. 4

Nodosaria aculeata D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 35, pl. 1, figs. 26, 27.

Specimens with generally globular chambers separated by distinct necks and the walls with rather stout spines occur in the Alazan clays on the Rio Buena Vista. Somewhat similar specimens occur in the Pacific Coast Eocene.

NODOSARIA SPINICOSTA d'Orbigny

Plate 24, figs. 5, 6

Nodosaria spinicosta D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 37, pl. 1, figs. 32, 33.

The figures show very well the characters of this species which was described by d'Orbigny from the Vienna Basin. It is figured by Hantken from the *Clavulina-Szaboi* beds of Hungary. It has a few closely set chambers, excavated on the lower border, ornamented with distinct raised longitudinal costae usually ending at the lower end of each chamber in a spinose extension; aperture with a tapering neck with circular costae. This species occurs in the Alazan clays collected by Dr. Vaughan on the Rio Buena Vista.

NODOSARIA FISSICOSTATA (Gümbel)

Plate 24, figs. 10, 11

Dentalina fissicostata GÜMBEL, Abhandl. Kön. bay. Akad. Wiss. München, Cl. II, vol. 10, 1868 (1870), p. 626, pl. 1, fig. 46.—HANTKEN, A. magy. Kir. födlt. int. évkönyve, vol. 4, 1875 (1876), p. 37, pl. 3, fig. 19; Mitth. Jahrb. ungar. geol. Anstalt, vol. 4, 1875 (1876), p. 37, pl. 3, fig. 19.

Nodosaria fissicostata CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 3, 1925, p. 66, pl. 10, fig. 8.

Test large, often slightly curved in the early portion, slightly tapering; chambers fairly numerous, earlier ones often obscured by the ornamentation, later ones inflated and distinct; surface ornamented with numerous fine longitudinal costae, continuous over the length of the test except for the new ones which come in between the older ones as the diameter of the chamber enlarges, aperture radiate, nearly if not quite central, slightly projecting.

Length, up to 6 mm.; maximum breadth, 0.60 mm.

This species is known from the Eocene of Bavaria, Hungary, and Italy at numerous localities. It is known from the Upper Eocene of the Coastal plain of the

United States from Alabama, Florida, Georgia, and South Carolina. In the Alazan of Mexico it was collected by Dr. Vaughan on the Rio Buena Vista.

NODOSARIA ACUMINATA Hantken

Plate 24, fig. 9

Nodosaria acuminata HANTKEN, A. magy. kir. földt. int. évkönyve, vol. 4, 1875 (1876), p. 23, pl. 2, fig. 9; Mitth. Jahrb. ungar. geol. Anstalt, vol. 4, 1875 (1881), p. 28, pl. 2, fig. 9.

Test slender, very slightly tapering, initial end with a stout spine; chambers distinct, longer than broad, the sutures slightly depressed, distinct; wall ornamented with a few (four to eight) thin plate-like costae continuous over the length of the test; aperture central, radiate, projecting.

Length, up to 2 mm. or more; diameter, 0.20 mm.

This species, known from the Eocene of Central Europe, occurs in some numbers at stations in the Alazan on the Rio Buena Vista collected by Dr. Vaughan.

NODOSARIA FONTINENSIS (Berthelin), var. VELASCOENSIS Cushman

Plate 28, fig. 5

Nodosaria fontannesi (BERTHELIN), var. *velascoensis* CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 594, pl. 18, fig. 12.

This is a large and striking form very common with a long vertical range in the Velasco shale.

NODOSARIA MEXICANA Cushman

Plate 24, figs. 15, 16

Nodosaria mexicana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 5, pl. 1, figs. 3, 4.

This is an abundant and characteristic species of the Tantoyuca occurring at many stations in this formation collected by Dr. Vaughan. The peculiar angular swelling in the middle of the chamber in the adult is characteristic. This is sometimes lost in old-age specimens.

Genus FRONDICULARIA Defrance, 1824

FRONDICULARIA BAUDOUINIANA (d'Orbigny)

Plate 24, fig. 13

Flabellina baudouiniana D'ORBIGNY, Mém. Soc. Geol. France, ser. 1, vol. 4, 1860, p. 24, pl. 2, figs. 8–11.

Frondicularia baudouiniana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, p. 21, pl. 3, fig. 5.

This species has already been recorded from the Mendez shale from near Las Palmas, Hacienda El Limon, San Luis Potosi, Mexico. It has a wide distribution in this formation.

Family NONIONIDAE

Genus NONION Montfort, 1826

Nonion MONTFORT (type *N. incrassatus* (Fichtel and Moll)), Conch. syst., vol. 1, 1808, p. 211, 53d genre.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 49.

Nonionina of D'ORBIGNY and later authors.

NONION UMBILICATULUS (Montagu), var.

Plate 25, figs. 12, 13

Specimens similar to that figured are very common in the Alazan clays collected by Dr. Vaughan, and are widely distributed in the Eocene and Lower Oligocene of the Gulf Coastal Plain of the United States.

Family HETEROHELICIDAE

Subfamily PAVONINAE

PAVONINA MEXICANA Cushman

Plate 25, figs. 14–16

Pavonina mexicana CUSHMAN, Proc. U. S. Nat. Mus., vol. 67, 1926, p. 22, pl. 6, figs. 7–9.

This is a very striking species collected by Dr. Vaughan in Alazan clays of the Rio Buena Vista, 0.5 km. 25° E. from Tumbadero Hacienda House, Vera Cruz, Mexico.

Figure 14 shows a young specimen with the early coiled stage with the biserial stage just starting. The various stages, coiled, biserial and uniserial, are well shown in the adult specimens figured. The wall often has arenaceous material clinging to it, but this apparently is not a part of the wall.

Subfamily GUEMBELININAE

Genus GUEMBELINA Egger, 1899

Textularia (in part) of authors.

Guembelina EGGER (type *Textularia globulosa* Reuss), Abhandl. Kön. bay. Akad. Wiss. München, Cl. II, vol. 21, 1899, p. 31.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 59.

Test with the early chambers planispiral, at least in the microspheric form, later chambers biserial; wall finely perforate, variously ornamented; aperture at the base of the inner margin of the last-formed chamber, usually large, arched, without teeth.

The species which belong in this genus have usually been placed in *Textularia*. That genus is arenaceous, while *Guembelina* has a calcareous perforate, usually hyaline test, and a very large aperture. The planispiral young shows its relation to *Heterohelix* and other genera of this family.

GUEMBELINA PUPA (Reuss)

Plate 27, fig. 6

Textularia pupa REUSS, Sitz. Akad. Wiss. Wien, vol. 40, 1860, p. 232, pl. 13, figs. 4, 5.—CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 584, pl. 15, figs. 5, 6.

Some of the specimens of the Velasco shale seem very close to this species of Reuss. There are others that may be referred to other species, but this one is very abundant at certain horizons.

GUEMBELINA EXCOLATA Cushman

Plate 28, fig. 13

Guembelina excolata CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 20, pl. 2, fig. 9.

In the upper portion of the Mendez, this species is very characteristic and often fairly abundant. The types are from the east bank of the Tamuin River, 5 km. SE. of Guerrero, San Luis Potosi, Mexico.

Genus PSEUDOTEXTULARIA Rzehak, 1886

Pseudotextularia RZEHAK (type *P. varians* Rzehak), Verh. Nat. Ver. Brunn, vol. 24, part 1, 1885 (1886), Sitz. p. 8.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 59.

Test with the early chambers as in *Guembelina*, but in the adult having a series of globular chambers arranged in a more or less spiral manner about the upper portion of the test.

PSEUDOTEXTULARIA VARIANS Rzehak

Plate 27, fig. 2

Pseudotextularia varians RZEHAK, Ann. K. K. Nathist. Hofmuseums, vol. 10, part 2, 1895, p. 217, pl. 7, figs. 1–3.

Guembelina fruticosa EGGER, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, 1899, p. 35, pl. 14, figs. 8, 9.

There are very large specimens often very abundant in the upper portion of the Mendez shales. The vertical range of the genus is very limited, but it has a wide geographical distribution.

Genus PLANOGLOBULINA Cushman, 1927

Guembelina (in part), EGGER, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21 1899, p. 36.

Pseudotextularia (in part) CUSHMAN, Jour. Wash. Acad. Sci., vol. 15, no. 6, 1925, p. 134; Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 17.

Planoglobulina CUSHMAN (type *P. acervulinoides* (Egger)), Contrib. Cushman Lab. Foram. Res., vol. 2, part 4, 1927, p. 77; vol. 3, part 1, 1927, p. 61.

Test with the earliest chambers in the microspheric form planispiral, followed by a series arranged biserially, and in the adult by a series of globular chambers spread out fan-shaped or even partially extending back toward the earlier chambers on either side, the later chambers in a single plane; wall calcareous, perforate.

This genus like *Pseudotextularia* developed from *Guembelina*. In some species there is a piling up of chambers to resemble the stage seen in *Pseudotextularia;* while in the others, especially the small species of the Taylor marl, this stage is wanting, and the flattened stage develops at once after the early *Guembelina*-like young.

PLANOGLOBULINA ACERVULINOIDES (Egger)

Plate 27, fig. 3

Guembelina acervulinoides EGGER, Abhandl. Kön. bay. Akad. Wiss. München, Cl. II, vol. 21, 1899, p. 36, pl. 14, figs. 17, 18, 20–22.

Pseudotextularia acervulinoides CUSHMAN, Jour. Wash. Acad. Sci., vol. 15, 1926, p. 134; Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 17.

Planoglobulina acervulinoides CUSHMAN, *op. cit.*, vol. 3, part 1, 1927, pl. 13, fig. 5.

This striking species is characteristic of the upper portion of the Mendez shale of Mexico. It is known from the Upper Cretaceous of the Bavarian Alps and from the Taylor marl of Texas.

Subfamily BOLIVINITINAE

Genus BOLIVINOIDES Cushman, 1927

Bolivina (in part) MARSSON, Mitth. Nat. Ver. Neu-Vorpommern u. Rügen, vol. 10, 1878, p. 157, pl. 3, figs. 25 *a–d*.

Bolivinoides CUSHMAN (Type *B. draco* (Marsson)), Contrib. Cushman Lab. Foram. Res., vol. 2, part 4, 1927, p. 89; vol. 3, part 1, 1927, p. 61.

Test compressed, rhomboid, the thickest portion near the aperture, this end usually appearing like a thickened lip without ornamentation, ornamentation in general at right angles to the sutures, aperture in the median line, elongate.

BOLIVINOIDES DECORATA (Jones), var. DELICATULA Cushman

Plate 28, fig. 7

Bolivina decorata CUSHMAN (not Jones), Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 582, pl. 15, fig. 11.

Bolivinoides decorata (JONES), var. *delicatula* CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 4, 1927, p. 90, pl. 12, fig. 8.

This variety is fairly common in the upper part of the Velasco shale with a very definite vertical range. The types are from the Velasco of Hacienda El Limon, Vera Cruz, Mexico.

BOLIVINOIDES RHOMBOIDEA (Cushman)

Plate 28, fig. 12

Bolivina rhomboidea CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 19, pl. 2, fig. 3 *a, b*.

Bolivinoides rhomboidea CUSHMAN, *op. cit.*, vol. 2, part 4, 1927, p. 90, pl. 12, figs. 10 *a, b*.

This is one of the species of short vertical range in the upper part of the Mendez shale. It is very easily recognized, and while it is related to the species of Texas and Europe, there is nothing else in the Mexican series that is likely to be confused with it. The types are from 5 km. southeast of Guerrero, on the Tamuin River, San Luis Potosi, Mexico.

BOLIVINOIDES VELASCOENSIS (Cushman)

Plate 28, fig. 10

Textularia velascoensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 18, pl. 3, figs. 1 *a–c*.—Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 584, pl. 15, fig. 8.

This species should probably be placed in *Bolivinoides*. The wall is calcareous, perforate, and very peculiarly ornamented with raised limbate sutures with irregular raised lines between forming a sort of mesh work. The initial end often projects and seems to be planispiral. In the Velasco, this species is a very characteristic one and has a wide vertical range.

Subfamily SPIROPLECTININAE

Genus SPIROPLECTOIDES Cushman, 1927

Spiroplecta EHRENBERG (in part), Mikrogeologie, 1854, pl. 32, part 2, fig. 36.

Spiroplectoides CUSHMAN (type *S. rosula* (Ehrenberg)), Contrib. Cushman Lab. Foram. Res., vol. 2, part 4, 1927, p. 77; *op. cit.*, vol. 3, part 1, 1927, p. 62.

Test with the early chambers planispiral, later ones biserial, elongate sides nearly parallel with biserial chambers very numerous; wall calcareous, perforate; aperture elliptical, terminal or nearly so in the adult.

SPIROPLECTOIDES CLOTHO (Grzybowski)

Plate 28, fig. 6

Spiroplecta clotho GRZYBOWSKI, Rozprawy Wydz. mat. przyr., vol. 41, 1901, p. 283, pl. 7, fig. 18.

Spiroplecta annectens CUSHMAN (not Parker and Jones), Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 584, pl. 15, figs. 4 *a*, *b*.

Test compressed, in the early stages planispiral, later ones forming nearly the whole of the test, biserial, periphery acute, chambers very numerous, broad and low, sutures distinct, slightly depressed or sometimes limbate; aperture at the terminal end, elongate.

This species was described by Grzybowski from the Cretaceous of Galicia. A further study of the specimens referred to *Spiroplecta annectens* from the Velasco of Mexico shows that they probably belong to *S. clotho*. The species has a very extensive vertical range in the Velasco, but does not occur in any other of the formations.

Family HANTKENINIDAE

Genus HANTKENINA Cushman, 1924

Hantkenina CUSHMAN, Proc. U. S. Nat. Mus., vol. 66, art. 30, 1924, p. 1.—Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 64.

Siderolina (in part) HANTKEN, A magy. kir földt. int. evkönyve, vol. 4, 1875 (1876), p. 68, pl. 16, fig. 1.

Test planispiral throughout, wall thin, calcareous, perforate; chambers distinct, involute, each with an acicular spine at the anterior angle or becoming obsolete in the adult, aperture typically arched with a basal lobe at either side.

This genus is characteristic of the Upper Eocene.

HANTKENINA ALABAMENSIS Cushman

Plate 25, fig. 17

Hantkenina alabamensis CUSHMAN, Proc. U. S. Nat. Mus., vol. 66, art. 30, 1924, p. 3, pl. 1, figs. 1–6, pl. 2, fig. 5; Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 7, pl. 1, fig. 11; *op. cit.*, part 3, 1925, p. 68.

This is the only species that occurs in the Alazan. It occurs also in the Upper Eocene (Jackson, of Alabama, Mississippi, Louisiana, and Texas. The spines are longer than in *H. brevispina* of the Tantoyuca and the form of the chambers in *H. mexicana* and *H. longispina* is very different.

HANTKENINA BREVISPINA Cushman

Plate 26, fig. 1

Hantkenina brevispina CUSHMAN, Proc. U. S. Nat. Mus., vol. 66, art. 30, 1924, p. 2, pl. 2, fig. 3.

The types of this species were from the Rio Pantepec, 2.2 km. S. 20° W. from Buena Vista, collected by Dr. Vaughan.

HANTKENINA LONGISPINA Cushman

Plate 26, fig. 2

Hantkenina longispina CUSHMAN, Proc. U. S. Nat. Mus., vol. 66, art. 30, 1925, p. 2, pl. 2, fig. 4; Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 299, pl. 7, fig. 3.

The types of this species are from dark gray clay, Rio Tuxpan, crossing of road from Palo Blanco to La Noria and along Rio Pantepec about 200 meters above its mouth, collected by Dr. Vaughan. It was also found in material of probable Tantoyuca age on the Moctezuma River near its junction with Rio Tamuin.

HANTKENINA MEXICANA Cushman

Plate 25, fig. 18

Hantkenina mexicana CUSHMAN, Proc. U. S. Nat. Mus., vol. 66, art. 30, 1924, p. 3, pl. 2, fig. 2.

This species is the most striking of all those of the genus having the very stout somewhat fusiform spines and the chambers extending out into lobes. The types are from La Laja, Zardo Creek, 1 km. S. W. of Tierra Colorado, Vera Cruz, Mexico, collected by Dr. Vaughan.

Family BULIMINIDAE

Subfamily BULIMINAE

Genus BULIMINA d'Orbigny, 1826

BULIMINA TRIHEDRA Cushman

Plate 27, fig. 5

Bulimina trihedra CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 591, pl. 17, figs. 6 *a*, *b*.

This small species can hardly be confused with any other in the Mexican series. It is distinctly trihedral in form, which is unusual in this genus. It is one of the common species in a limited zone in the upper part of the Velasco shale.

BULIMINA ALAZANENSIS Cushman, n. sp.

Plate 25, fig. 4

Test small, somewhat longer than broad, greatest breadth near the apertural end, thence tapering to the initial end; chambers and sutures obscured by the ornamentation which consists of prominent longitudinal costae ending at the basal end in somewhat spinose projections, surface often slightly corrugated between the costae; aperture elongate, somewhat comma-shaped.

Length, 0.50 mm. or less.

Holotype (U. S. Nat. Mus., No. 369307) collected by Dr. T. Wayland Vaughan from the type locality of the Alazan clay, Rio Buena Vista, just south of crossing of Alazan to Moyutla Road, Vera Cruz, Mexico. It also occurred in Alazan material collected by Dr. Vaughan on the Rio Buena Vista, 2 km. in a straight line above its confluence with Rio Tuxpan; Rio Buena Vista, 9.8 km. in a straight line upstream from Tumbadero and Arroyo Camalla; Tepitzintla–El Humo road, about 4 km. east of El Humo.

The species is related to *Bulimina buchiana* d'Orbigny and *B. rostrata* H. B. Brady.

Subfamily VIRGULININAE

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA INCRASSATA Reuss

Plate 28, fig. 11

Bolivina incrassata REUSS, Haidinger's Nat. Abh., vol. 4, part 1, 1851, p. 45, pl. 4, fig. 13.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 19, pl. 2, figs. 1 *a*, *b*; part 4, 1927, p. 86, pl. 12, figs. 1 *a*, *b*.

In the upper portion of the Mendez shale this is one of the characteristic and often abundant species. It is widely distributed in the Upper Cretaceous of the United States and Europe.

BOLIVINA INCRASSATA Reuss, var. LIMONENSIS Cushman

Plate 27, fig. 4

Bolivina incrassata REUSS, var. *limonensis* CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 19, pl. 2, fig. 2; part 3, 1927, p. 86.

In the Mendez shale is this very elongate variety, which is often associated with the typical form but apparently does not occur with it in the Upper Cretaceous of the United States.

BOLIVINA MEXICANA Cushman

Plate 28, fig. 9

Bolivina mexicana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 81, pl. 12, fig. 2.

This and the following varieties are characteristic of the Alazan clays and have a wide distribution as well as often being very abundant. The type specimen was from clays on the Panuco Railroad between Kilometer Posts 21 and 22, Vera

Cruz, Mexico. It was found also by Dr. Vaughan in the typical Alazan clays on the Rio Buena Vista and elsewhere. The two following varieties may be distinguished.

BOLIVINA MEXICANA Cushman, var. ALIFORMIS Cushman

Plate 24, fig. 18

Bolivina mexicana CUSHMAN, var. *aliformis* CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 82, pl. 12, figs. 3, 4.

In this variety there is a very broad, thin carina developed about the entire periphery of the test. It is limited in its vertical distribution, although it has a rather wide horizontal distribution. The type locality is Alazan shale, left bank of Tuxpan River, at bluff S. 25° E., about 0.5 km. from Tumbadero Hacienda House, Vera Cruz, Mexico, collected by Dr. T. Wayland Vaughan. At the type station, it is very abundant.

BOLIVINA MEXICANA Cushman, var. HORIZONTALIS Cushman

Plate 28, fig. 8

Bolivina mexicana CUSHMAN, var. *horizontalis* CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 82, pl. 12, figs. 5 *a–b*.

This variety has the keel deeply cut with projecting areas between, the general axes of which are horizontal. At one particular zone in the Alazan this variety is very abundant. The type locality is from Alazan clay, southwest slope of Cuesta Blanca, near Zacamixtle, Vera Cruz, Mexico; collected by Dr. Vaughan.

BOLIVINA ALAZANENSIS Cushman

Plate 25, fig. 1

Bolivina alazanensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 82, pl. 12, figs. 1 *a*, *b*.

This is probably the most abundant species of the genus in the Alazan. It has a very slight development of the keel; and the outer basal angles of the chambers are slightly projecting, the central zigzag line often raised. The types are from the Tampico-Panuco Railroad, Kilometer Post 20.15. It was collected by Dr. Vaughan at numerous stations on the Rio Buena Vista and elsewhere.

BOLIVINA TECTIFORMIS Cushman

Plate 25, fig. 2

Bolivina tectiformis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 83, pl. 12, figs. 6 *a*, *b*.

Although smaller than the preceding ones, this species is very abundant and well characterized in the Alazan clays.

The types were collected by Dr. Vaughan at the type station of the Alazan on the Rio Buena Vista. The broadly rounded ends, nearly straight sides, and the peculiar transparent middle area in each chamber surrounded by the nearly opaque border make it a very distinctive species. The median line is often strongly raised.

Genus RECTOBOLIVINA Cushman, 1927

Siphogenerina (in part) of various authors.

Rectobolivina CUSHMAN (type *R. bifrons* (H. B. Brady)), Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 68.

Test in the young biserial, in the adult uniserial, usually compressed, wall thin, finely perforate, aperture rounded or elliptical, with a slight lip and internal tube.

This genus includes those species usually assigned to *Siphogenerina* but which apparently developed directly from *Bolivina* instead of through the Uvigerine series. The aperture does not have a contracted neck and broad lip, but is elongate, rounded, and with only a slight raised border.

RECTOBOLIVINA MEXICANA (Cushman)

Plate 24, fig. 17

Siphogenerina mexicana CUSHMAN, Proc. U. S. Nat. Mus., vol. 67, 1926, p. 15, pl. 5, figs. 4 *a*, *b*.

This species is often very abundant in the Alazan clay and is limited in its vertical range. It can hardly be confused with any other Mexican form. The species also occurs in the Eocene of the Gulf Coastal Plain. The types were collected by Dr. Vaughan from the Alazan clays of the Rio Buena Vista.

Subfamily UVIGERININAE

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA JACKSONENSIS Cushman

Plate 25, fig. 3

Uvigerina jacksonensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 3, 1925, p. 67, pl. 10, fig. 13.

The type specimens of this species came from the Cocoa sand of the Jackson Eocene of Alabama. The species is widely distributed in the Upper Eocene and occurs in the Alazan clays of Mexico at numerous localities. It is probably the commonest and largest of the Mexican Uvigerinas.

Family ROTALIIDAE

Subfamily DISCORBISINAE

Genus DISCORBIS Lamarck, 1804

Discorbis LAMARCK (type *D. vesicularis* Lamarck), Ann. Mus., vol. 5, 1804, p. 183.—CUSHMAN, Bull. 71, U. S. Nat. Mus., part 5, 1915, p. 10; Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 76.

Discorbina (in part) of authors.

Test typically plano-convex, the ventral side flattened, early portion sometimes showing a long *Spirillina*-like chamber before division; chambers often pro-

duced to partially cover the umbilical area; aperture, a slit on the umbilical margin of the ventral side of the chamber.

The genotype of *Discorbis* is *D. vesicularis*, a large and common species from Grignon in the Paris Basin Eocene.

DISCORBIS VAUGHANI Cushman, n. sp.

Plate 25, figs. 5, 6

Discorbis patelliformis CUSHMAN (not H. B. Brady), U. S. Geol. Survey, Prof. Paper 133, 1923, p. 38, pl. 6, figs. 3, 4.

Test free, plano-convex, dorsal side somewhat convex, ventral side flattened, peripheral edge acute, in the adult with about three coils, with about seven chambers in the coil; distinct but not inflated; sutures curved, slightly limbate, not depressed, confluent with the peripheral keel; wall on the dorsal side smooth, finely perforate, ventrally with granulations on the umbilical surface, and more coarsely perforate; aperture ventral, elongate, near the umbilicus.

Diameter, 0.5 mm.

Holotype (U. S. Nat. Mus., No. 369308) from Alazan clays on Rio Buena Vista near crossing of Alazan-Moyutla Road, collected by Dr. T. Wayland Vaughan for whom the species is named.

This is the same as the species I have figured in the above reference from the Lower Oligocene of Mississippi.

Genus GYROIDINA d'Orbigny, 1826

Gyroidina D'ORBIGNY (type *G. orbicularis* d'Orbigny), Ann. Sci. Nat., vol. 7, 1826, p. 278.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 76.

Rotalia (in part) of authors.

Test with the ventral side convex, the umbilicus usually small and deep, chambers in the central region usually higher than the peripheral ones and separated by a depressed channel; aperture, a low-arched opening on the ventral side toward the umbilical area.

This genus differs from *Rotalia* where the umbilicus is typically filled with a solid plug of calcareous material.

GYROIDINA GIRARDANA (Reuss)

Plate 25, figs. 7–9

Rotalina girardana REUSS, Zeitschr. deutsch. geol. Ges., vol. 3, 1851, p. 73, pl. 5, fig. 34.

The form figured seems to be identical with Reuss' species. It is a common species of the Alazan clays and was collected by Dr. Vaughan at numerous localities.

Genus ROTALIATINA Cushman, 1925

Rotaliatina CUSHMAN (type *R. mexicana* Cushman), Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 4; vol. 3, part 1, 1927, p. 76.

Test with the ventral side very convex, the umbilicus small and deep, test with a high spire; wall calcareous, finely perforate; aperture, an arched opening on the ventral side midway between the umbilicus and periphery.

ROTALIATINA MEXICANA Cushman

Rotaliatina mexicana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 4, pl. 1, fig. 1 *a–c*.

This species can hardly be mistaken for anything else in the Mexican series. It is widely spread in the Alazan clays, but its vertical range is not great. The types are from Alazan shale, $2\frac{1}{3}$ km. SW. of Carrizo, on the Rio Tamuin, San Luis Potosi, Mexico. Dr. Vaughan collected the species at the type exposure of the Alazan on Rio Buena Vista.

Subfamily ROTALIINAE

Genus EPONIDES Montfort, 1808

Eponides MONTFORT (type *E. repandus* (Fichtel and Moll)), Conch. Syst., vol. 1, 1808, p. 127, 32 genre.—CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 76.

Pulvinulina (in part) of authors.

Test usually biconvex, trochoid, umbilical area closed; wall calcareous, finely perforate; aperture, a low opening between the periphery and umbilical area usually well away from the peripheral margin; test often with thickened sutures and walls.

EPONIDES MEXICANA (Cushman)

Plate 26, figs. 6, 7

Pulvinulina mexicana CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 9, 1925, p. 300, pl. 7, figs. 7, 8.

This is one of the most common species of the Tantoyuca formation. It was originally described from Eocene deposits of this age on the Moctezuma River near the mouth of the Rio Tamuin. In his collecting, Dr. Vaughan obtained material containing this species in great numbers at numerous stations in the Tantoyuca formation. The same species seems to be widely distributed in the Claiborne of the Gulf Coastal Plain, and it occurs in the Eocene of the Pacific Coast. There are a number of closely allied species in the Jackson and Lower Oligocene.

EPONIDES SPINEA (Cushman)

Plate 27, fig. 1

Truncatulina spinea CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 22, pl. 2, figs. 10 *a–c*.

This is a characteristic species of the upper part of the Mendez shale. The dorsal side is flattened or concave with the periphery projecting at the angles of the chambers with spinose ends, ventral side very convex. The types are from Mendez shale on the Guerrero-Taninul road, San Luis Potosi, Mexico. Its vertical range is very restricted, but it occurs over a wide area.

Genus ROTALIA Lamarck, 1804

Rotalia LAMARCK (type *R. trochidiformis* LAMARCK), Ann. Mus., vol. 5, 1804, p. 184.

Test usually biconvex, the umbilical area closed, and usually having a conical plug of clear shell material, sutures on the ventral side usually deeply depressed and often ornamented along the sides; wall often double; aperture, an arched opening at the border of the ventral face midway between the periphery and the umbilical area, interseptal canals sometimes present.

ROTALIA, sp.?

Plate 26, fig. 5

This species occurs in some numbers in the Alazan clays, but is not usually well preserved. The ventral side is here figured to call attention to this peculiar form which in some respects is related to *Rotalia byramensis* Cushman as well as to certain of the living Indo-Pacific species. It is the most interesting species of the genus in the Mexican Tertiary.

Subfamily SIPHONININAE

EPISTOMINA ELEGANS (d'Orbigny)

Plate 26, figs. 3, 4

Rotalia elegans D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 272.—JONES AND PARKER, Quar. Jour. Geol. Soc., vol. 16, 1860, pl. 20, fig. 46.

Pulvinulina elegans PARKER, JONES AND BRADY, Ann. Mag. Nat. Hist., ser. 4, vol. 8, 1871, p. 174, pl. 12, fig. 142.

Species very close to this occur in the Upper Cretaceous of Texas and through the Eocene series. In the Mexican area, this species is characteristic of the Alazan.

Genus SIPHONINA Reuss, 1849

SIPHONINA TENUICARINATA Cushman, n. sp.

Plate 26, figs. 11, 12

Test biconvex, trochoid, last-formed coil with about five chambers, distinct on the ventral side, but less so on the dorsal, sutures on the ventral side distinct, very slightly depressed, indistinct on the dorsal side; periphery with a broad, thin keel, the edge entire except for accidental breaks; aperture elongate, elliptical slightly on the ventral side, with a very short neck, hardly developed, and a broadly rounded, thick lip.

Diameter, 0.6 mm.

Holotype (U. S. Nat. Mus., No. 369309) from the typical Alazan on the Rio Buena Vista just south of crossing of Alazan to Moyutla road, collected by Wayland Vaughan, who also collected it on the same river 2 km. in a straight line above its confluence with Rio Tuxpan, and 0.5 km. S. 25° E. from Tumbadero Hacienda House, also 9.8 km. in a straight line upstream from Tumbadero; Rio la

Puerto, Soledad crossing and Arroyo Camalla, Tepitzintla–El Humo road, about 4 km. E. of El Humo.

It is a characteristic species of the Alazan, and a very similar form also occurs in Trinidad.

Family CASSIDULINIDAE

Subfamily CERATOBULIMININAE

Genus PULVINULINELLA Cushman, 1926

Pulvinulinella CUSHMAN (type *P. subperuviana* Cushman), Contrib. Cushman Lab. Foram. Res., vol. 2, part 3, 1926, p. 62.
Truncatulina (in part) of authors.

Test rotaliform, compressed, umbilical area closed, the last few chambers alternating in relative length, every other one slightly longer; aperture elongate, extending into the apertural face on the ventral side near the periphery and parallel to it.

PULVINULINELLA CULTER (Parker and Jones)

Plate 26, figs. 8, 9

Planorbulina culter PARKER AND JONES, Philos. Trans., vol. 155, 1865, p. 421, pl. 19, figs. 1 *a*, *b*.
Truncatulina culter H. B. BRADY, Rep. Voy. *Challenger*, Zoölogy, vol. 9, 1884, p. 668, pl. 96, figs. 3 *a–c*.

There is a fairly common species in the Alazan clays that may be referred to this species of Parker and Jones. It does not have the regular thickenings above the sutures as the recent species and the keel is not so distinctly serrate, but in many respects the two are similar. The aperture is oblique to the line of the edge of the chamber.

Subfamily CASSIDULININAE

Genus CASSIDULINA d'Orbigny, 1826

CASSIDULINA GLOBOSA Hantken

Plate 26, fig. 13

Cassidulina globosa HANTKEN, A magy. kir. földt. int. évkönyve, vol. 4, 1875 (1876), p. 54, pl. 16, fig. 2; Mitth. Jahrb. ungar. geol. Anstalt, vol. 4, 1875 (1881), p. 64, pl. 16, fig. 2.

This small species of *Cassidulina* is well distributed in the Upper Eocene being described from Hungary and now is known from the Jackson Eocene of the Gulf Coastal Plain. The figured specimen is from the Alazan. It was collected at several points on the Rio Buena Vista by Dr. Vaughan.

Family CHILOSTOMELLIDAE

Subfamily CHILOSTOMELLINAE

Genus CHILOSTOMELLOIDES Cushman, 1926

Lagena (in part) SHERBORN AND CHAPMAN, Jour. Roy. Micr. Soc., 1886, p. 745.
Chilostomella (in part) SHERBORN AND CHAPMAN, *op. cit.*, 1889, p. 485.
Chilostomelloides CUSHMAN (type *C. oviformis* (Sherborn and Chapman)), Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 77.

Test similar to *Chilostomella*, but the aperture rounded and somewhat offset from the general contour of the test, with a neck in some species and slightly developed lip.

CHILOSTOMELLOIDES OVIFORMIS (Sherborn and Chapman)

Plate 26, fig. 10

Lagena (Obliquina) oviformis SHERBORN AND CHAPMAN, Jour. Roy. Micr. Soc., 1886, p. 745, pl. 14, figs. 19 *a–d*.

Chilostomella oviformis SHERBORN AND CHAPMAN, Jour. Roy. Micr. Soc., 1889, p. 485, pl. 11, fig. 13.

Chilostomelloides oviformis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 4, 1926, p. 77, pl. 11, figs. 17 *a–d*, 21 *a–c*.

In the typical Alazan clays collected by Dr. Vaughan on the Rio Buena Vista occur specimens which seem to be identical with those described by Sherborn and Chapman from the London clay. The aperture is offset as shown in the figure.

Genus PULLENIA Parker and Jones, 1862

PULLENIA ALAZANENSIS Cushman, n. sp.

Plate 26, figs. 14, 15

Test in the adult bilaterally symmetrical, planispiral, five chambers in the last formed coil; sutures slightly curved, slightly depressed; wall smooth, perforate, apertural face slightly flattened, and a few deep punctae symmetrically arranged; aperture, a low curved slit between the base of the chamber and the preceding whorl.

Diameter, 0.5 mm.; breadth, 0.20 mm.

Holotype (U. S. Nat. Mus., No. 369310) from Alazan clays on the Rio Buena Vista above crossing of Alazan-Moyutla Road, collected by Dr. T. Wayland Vaughan, who collected it at other points on the same river.

The species resembles *Pullenia quinqueloba* Reuss, except in the apertural face and the less regular chambers.

Family GLOBIGERINIDAE

Subfamily GLOBIGERININAE

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA MEXICANA Cushman

Plate 26, figs. 16, 17

Globigerina mexicana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 6, pl. 1, figs. 8 *a*, *b*.

This is one of the most striking species of the genus in the Mexican collections. It is nearly spherical yet has a trochoid arrangement of the chambers. It is found only in the Tantoyuca. The types came from Palacho Hacienda, south of Panuco, Tampico Railroad, Vera Cruz, Mexico. It was collected by Dr. Vaughan near Tantoyuca, Mexico.

Family GLOBOROTALIIDAE

Genus GLOBOTRUNCANA Cushman, 1927

Globotruncana CUSHMAN (type *G. arca* (Cushman)), Contrib. Cushman Lab. Foram. Res., vol. 3, part 1, 1927, p. 91.
Pulvinulina (in part) of authors.

Test trochoid, the adult usually much compressed, the dorsal and ventral sides either flat or convex, ventral side sometimes slightly concave, the periphery truncate, usually with a double keel in the dorsal and ventral sides; aperture on the ventral side, apparently pelagic in part.

GLOBOTRUNCANA ARCA (Cushman)

Plate 28, fig. 15

Pulvinulina arca CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, part 1, 1926, p. 23, pl. 3, figs. 1 *a–c*.
Globotruncana arca CUSHMAN, *op. cit.*, vol. 3, part 1, 1927, pl. 19, fig. 11.

This species is very abundant and characteristic of the Mendez shale. It is the most common species of that formation and will serve to identify it. There are several varietal forms or possibly distinct species. One of these, with a fairly high spire and concave areas giving a pyramidal appearance to the test, is *G. arca*, var. *contusa* (Cushman). Another species, with stout spines at the margin, is *G. calcarata* Cushman. The small form with flattened sides is probably *G. canaliculata* (Reuss). The last has also a very great vertical range.

Genus GLOBOROTALIA Cushman, 1927

Globorotalia CUSHMAN (type *G. tumida* (H. B. Brady)), Contrib. Cushman Lab. Foram. Res. vol. 3, part 1, 1927, p. 91.
Pulvinulina (in part) of authors.

Test trochoid, early chambers often like *Globigerina*, dorsal side often flat, the ventral side broadly convex, aperture usually in the umbilicus, wall frequently roughened throughout, mostly pelagic.

GLOBOROTALIA VELASCOENSIS (Cushman)

Plate 27, figs. 7–9

Pulvinulina velascoensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 19, pl. 3, figs. 5 *a–c;* Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 608, pl. 21, figs. 9 *a*, *b*.

This species is probably the most abundant one of the Velasco shale, especially of the lower and middle portions. It was evidently a pelagic species and dominated the seas at that time as far as the foraminifera were concerned.

Family ANOMALINIDAE

Subfamily ANOMALININAE

Genus ANOMALINA d'Orbigny, 1826

ANOMALINA UMBONATA Cushman

Plate 27, figs. 10, 11

Anomalina umbonata CUSHMAN, Bull. Amer. Assoc. Petr. Geol., vol. 9, 1925, p. 300, pl. 7, figs. 5, 6.

In the Tantoyuca this is one of the characteristic and dominant species. It was originally described from the Moctezuma River near its junction with the Rio Tamuin. Dr. Vaughan collected the species in the Tantoyuca in the neighborhood of the town of that name.

ANOMALINA VELASCOENSIS Cushman

Plate 28, fig. 14

Anomalina velascoensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, part 1, 1925, p. 21, pl. 3, figs. 3 *a–c;* Bull. Amer. Assoc. Petr. Geol., vol. 10, 1926, p. 607, pl. 21, figs. 7 *a–c*.

One of the most widely distributed species in the Velasco shale is the peculiar shaped *Anomalina*. It does not occur in the uppermost portion.

Genus PLANULINA d'Orbigny, 1826

PLANULINA MEXICANA Cushman

Planulina mexicana CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, part 2, 1927, p. 113, pl. 23, figs. 5 *a*, *b*.

This is one of the finest species of the Alazan clays. It was collected by Dr. Vaughan on the Rio Buena Vista.

Subfamily CIBICIDINAE

Genus CIBICIDES Montfort, 1808

Cibicides MONTFORT (type *C. refulgens* MONTFORT), Conch. Syst., vol. 1, 1808, p. 123.
Truncatulina (in part) authors.

Test close-coiled, trochoid, attached by the flattened dorsal side, aperture extending over onto the dorsal side from the periphery and forming an elongate slit along the inner margin of the chamber.

CIBICIDES LOBATULUS (Walker and Jacob)

Plate 27, figs. 12, 13

Nautilus lobatulus WALKER AND JACOB, Adam's Essays, Kanmacher's ed., 1798, p. 642, pl. 14, fig. 36.
Serpula lobatula MONTAGU, Test. Brit., 1803, p. 515; Suppl., p. 160.
Truncatulina lobatula D'ORBIGNY, in Barker, Webb and Berthelot Hist. Nat. Iles. Canaries, vol. 2, part 2, "Foraminiferes," 1839, p. 134, pl. 2, figs. 22–24.

This very variable species may include the form figured here which is common in the Alazan clays. Similar forms occur widely distributed in the Tertiary of various regions.

EXPLANATION OF PLATES

PLATE 23

FIG. 1.—*Textularia dibollensis* Cushman and Applin, ×60. Alazan.
2.—*T. subhauerii* Cushman, ×60. Alazan.
3.—*Textularia* cf. *hockleyensis* Cushman and Applin, ×30. Tantoyuca.
4.—*Rzehakina epigona* (Rzehak), ×60. Velasco.
5.—*Massilina jacksonensis* Cushman, n. sp., ×60. Microspheric form. Alazan.
6.—*M. jacksonensis* Cushman, n. sp., ×60. Megalospheric form. Alazan.
7.—*Robulus cultratus* Montfort, ×30. Alazan.
8.—*R. mexicanus* (Cushman), ×60. Tantoyuca.
9.—*R. gutticostatus* Gümbel, ×30. Alazan.
10.—*Robulus* cf. *vaughani* (Cushman) (?), ×30. Alazan.
11.—*R. budensis* Hantken, ×30. Alazan.
12.—*Cristellaria convergens* Bornemann, ×30. Alazan.
13.—*C. alazanensis* Cushman, n. sp., ×30. Alazan.

PLATE 24

FIG. 1, 2.—*Nodosaria ewaldi* Reuss, ×30. Alazan.
3.—*N. jacksonensis* Cushman and Applin, ×30. Alazan.
4.—*N. aculeata* d'Orbigny, ×50. Alazan.
5, 6.—*N. spinicosta* d'Orbigny, ×50. Alazan.
7, 8.—*Dentalina multilineata* Bornemann, ×30. Alazan.
9.—*Nodosaria acuminata* Hantken, ×50. Alazan.
10, 11.—*N. fissicostata* (Gümbel), ×30. Alazan.
12.—*Marginulina jacksonensis* (Cushman and Applin), ×50. Alazan.
13.—*Frondicularia baudouiniana* (d'Orbigny), ×30. Mendez.
14.—*Dentalina cocoaensis* (Cushman), ×30. Alazan.
15, 16.—*Nodosaria mexicana* Cushman, ×30. Tantoyuca.
17.—*Rectobolivina mexicana* (Cushman), ×60. Alazan.
18.—*Bolivina mexicana* Cushman, var. *aliformis* Cushman, ×60. Alazan.

PLATE 25

FIG. 1.—*Bolivina alazanensis* Cushman, ×60. Alazan.
2.—*B. tectiformis* Cushman, ×60. Alazan.
3.—*Uvigerina jacksonensis* Cushman, ×60. Alazan.
4.—*Bulimina alazanensis* Cushman, n. sp., ×60. Alazan.
5, 6.—*Discorbis vaughani* Cushman, n. sp., ×60. Alazan.
7–9.—*Gyroidina girardana* (Reuss), ×60. Alazan. 7, ventral; 8, peripheral; 9, dorsal view.
10.—*Nonion hantkeni* (Cushman and Applin), ×60. Alazan.
11.—*Plectofrondicularia vaughani* Cushman, ×35. Alazan.
12, 13.—*Nonion umbilicatulus* (Montagu), var., ×60. Alazan.
14–16.—*Pavonina mexicana* Cushman. 14, early stages, ×60. 15, 16, adults, ×30. Alazan.
17.—*Hantkenina alabamensis* Cushman, ×60. Alazan.
18.—*H. mexicana* Cushman, ×60. Tantoyuca.

PLATE 26

FIG. 1.—*Hantkenina brevispina* Cushman, ×60. Tantoyuca.
2.—*H. longispina* Cushman, ×60. Tantoyuca.
3, 4.—*Epistomina elegans* (d'Orbigny), ×30. Alazan.
5.—*Rotalia* sp.? ×30. Alazan.
6, 7.—*Eponides mexicana* (Cushman), ×30. Tantoyuca. 6, ventral; 7, dorsal view.
8, 9.—*Pulvinulinella culter* (Parker and Jones), ×30. Alazan. 8, dorsal; 9, ventral view.
10.—*Chilostomelloides oviformis* (Sherborn and Chapman), ×30. Alazan.

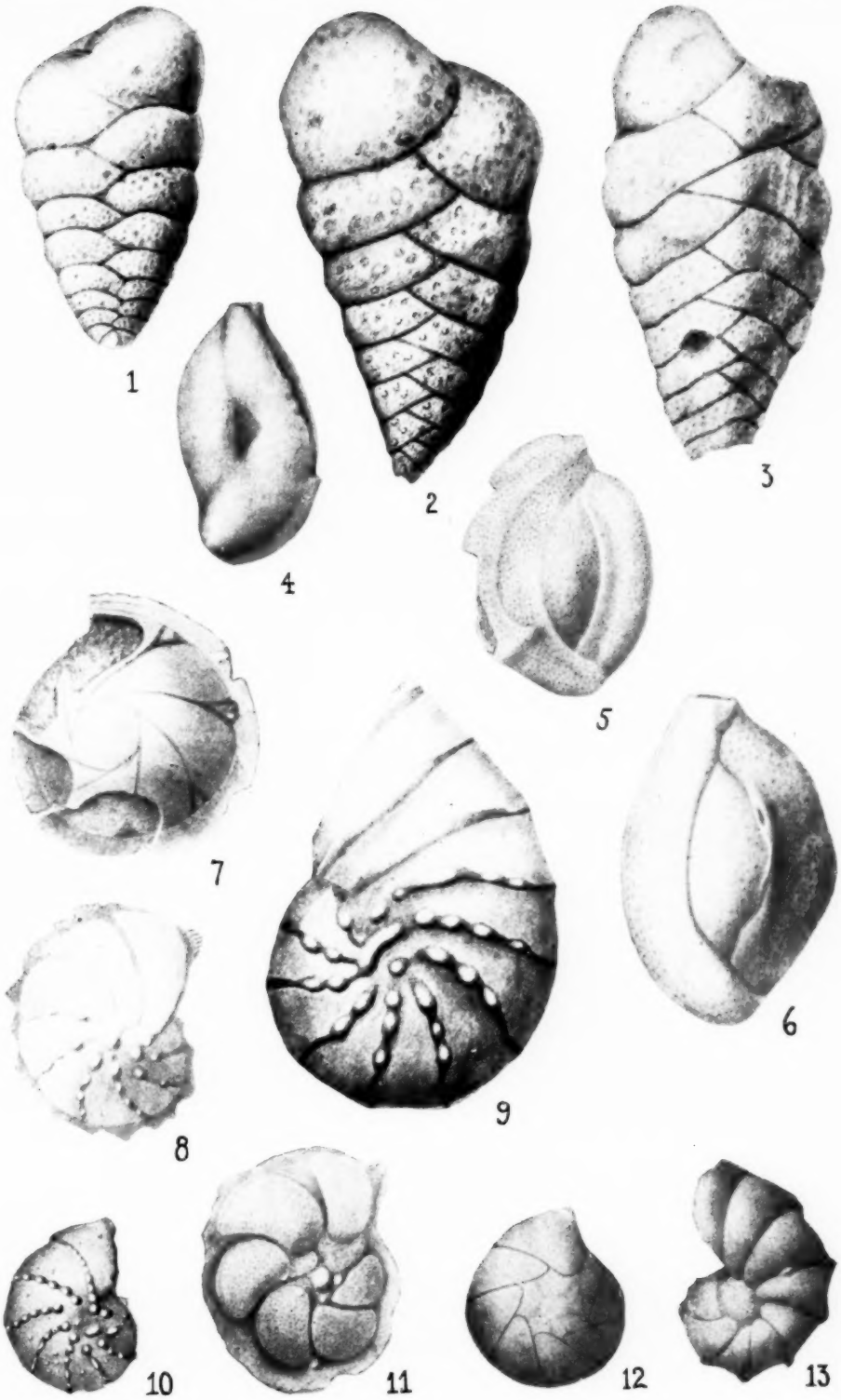
11, 12.—*Siphonina tenuicarinata* Cushman, n. sp., ×60. Alazan.
13.—*Cassidulina globosa* Hantken, ×60. Alazan.
14, 15.—*Pullenia alazanensis* Cushman, n. sp., ×60. Alazan.
16, 17.—*Globigerina mexicana* Cushman, ×30. Tantoyuca.

PLATE 27

FIG. 1 *a–c*.—*Eponides spinea* (Cushman), ×100. Mendez. *a*, dorsal view; *b*, side view; *c*, ventral view.
2 *a, b*.—*Pseudotextularia varians* Rzehak, ×50. Mendez. *a*, front view; *b*, end view.
3.—*Planoglobulina acervulinoides* (Egger), ×50. Mendez.
4.—*Bolivina incrassata* Reuss, var. *limonensis* Cushman, ×45. Mendez.
5.—*Bulimina trihedra* Cushman, ×50. Velasco. *a*, front view; *b*, apertural view.
6.—*Guembelina pupa* (Reuss), ×50. Velasco. *a*, front view; *b*, side view.
7.—*Globorotalia velascoensis* (Cushman), ×60. Velasco. Dorsal view.
8.—*G. velascoensis* (Cushman), ×60. Velasco. Side view.
9.—*G. velascoensis* (Cushman), ×60. Velasco. Ventral view.
10.—*Anomalina umbonata* Cushman, ×60. Tantoyuca. Dorsal view.
11.—*A. umbonata* Cushman, ×60. Tantoyuca. Ventral view.
12.—*Cibicides lobatulus* (Walker and Jacob), ×30. Alazan. Dorsal view.
13.—*C. lobatulus* (Walker and Jacob), ×30. Alazan. Ventral view.

PLATE 28

FIG. 1.—*Clavulina trilatera* Cushman, ×50. Velasco.
2.—*Gaudryina velascoensis* Cushman, ×50. Velasco.
3.—*Clavulina clavata* Cushman, ×50. Velasco.
4.—*Vulvulina spinosa* Cushman, ×30. Alazan.
5.—*Nodosaria fontinensis* (Berthelin), var. *velascoensis* Cushman, ×35. Velasco.
6 *a, b*.—*Spiroplectoides clotho* (Grzybowski), ×50. Velasco. *a*, front view; *b*, apertural view.
7.—*Bolivinoides decorata* (Jones), var. *delicatula* (Cushman), ×60. Velasco.
8.—*Bolivina mexicana* Cushman, var. *horizontalis* (Cushman), ×50. Alazan.
9.—*B. mexicana* Cushman, ×50. Alazan.
10.—*Bolivinoides velascoensis* (Cushman), ×50. Velasco.
11 *a, b*.—*Bolivina incrassata* Reuss, ×30. Mendez. *a*, front view; *b*, apertural view.
12 *a, b*.—*Bolivinoides rhomboidea* (Cushman), ×45. Mendez. *a*, front view. *b*, apertural view.
13.—*Guembelina excolata* Cushman, ×65. Mendez.
14 *a, b*.—*Anomalina velascoensis* Cushman, ×35. Velasco. *a*, side view; *b*, dorsal view.
15 *a–c*.—*Globotruncana arca* (Cushman), ×65. Mendez. *a*, dorsal view; *b*, peripheral view; *c*, ventral view.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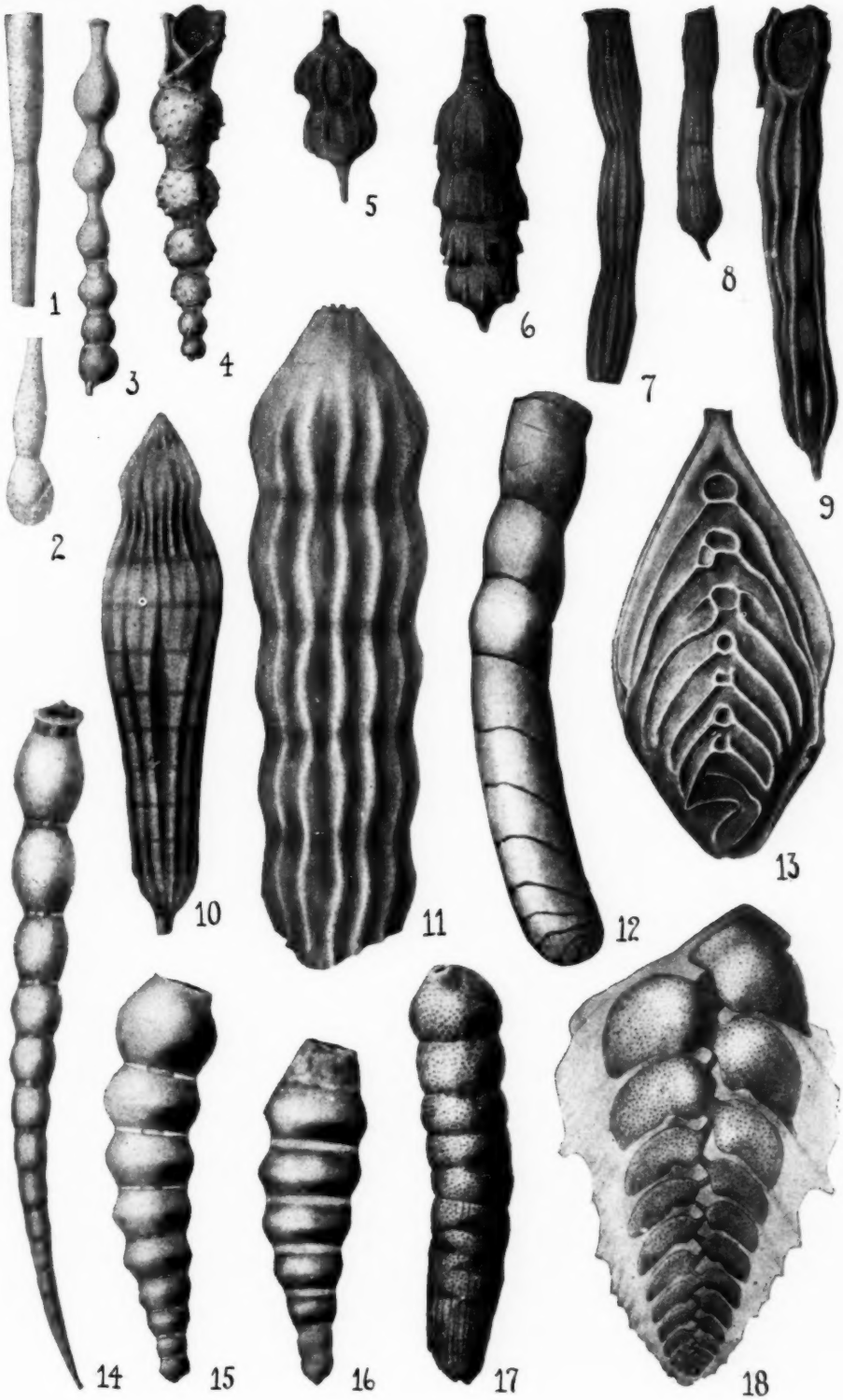
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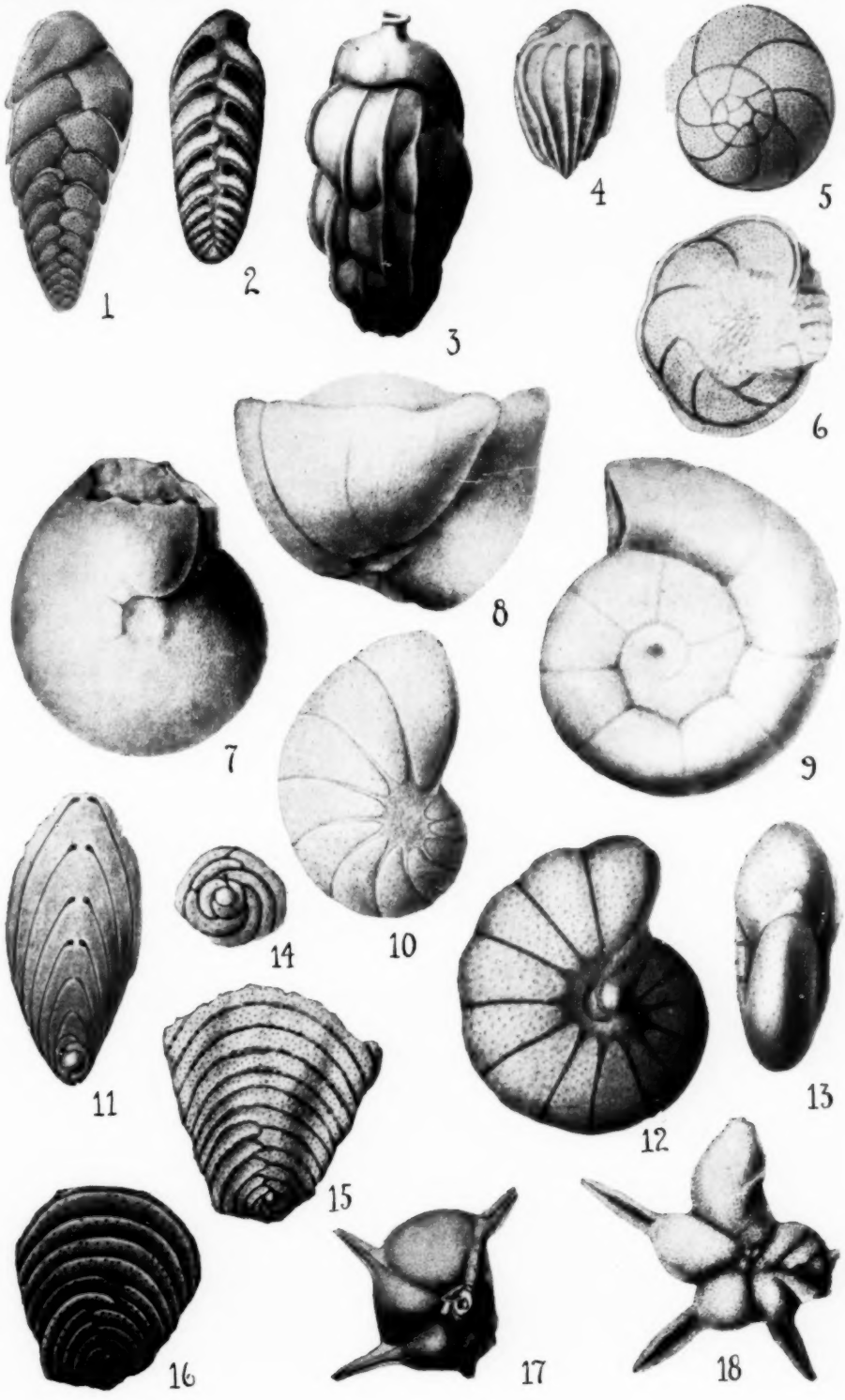
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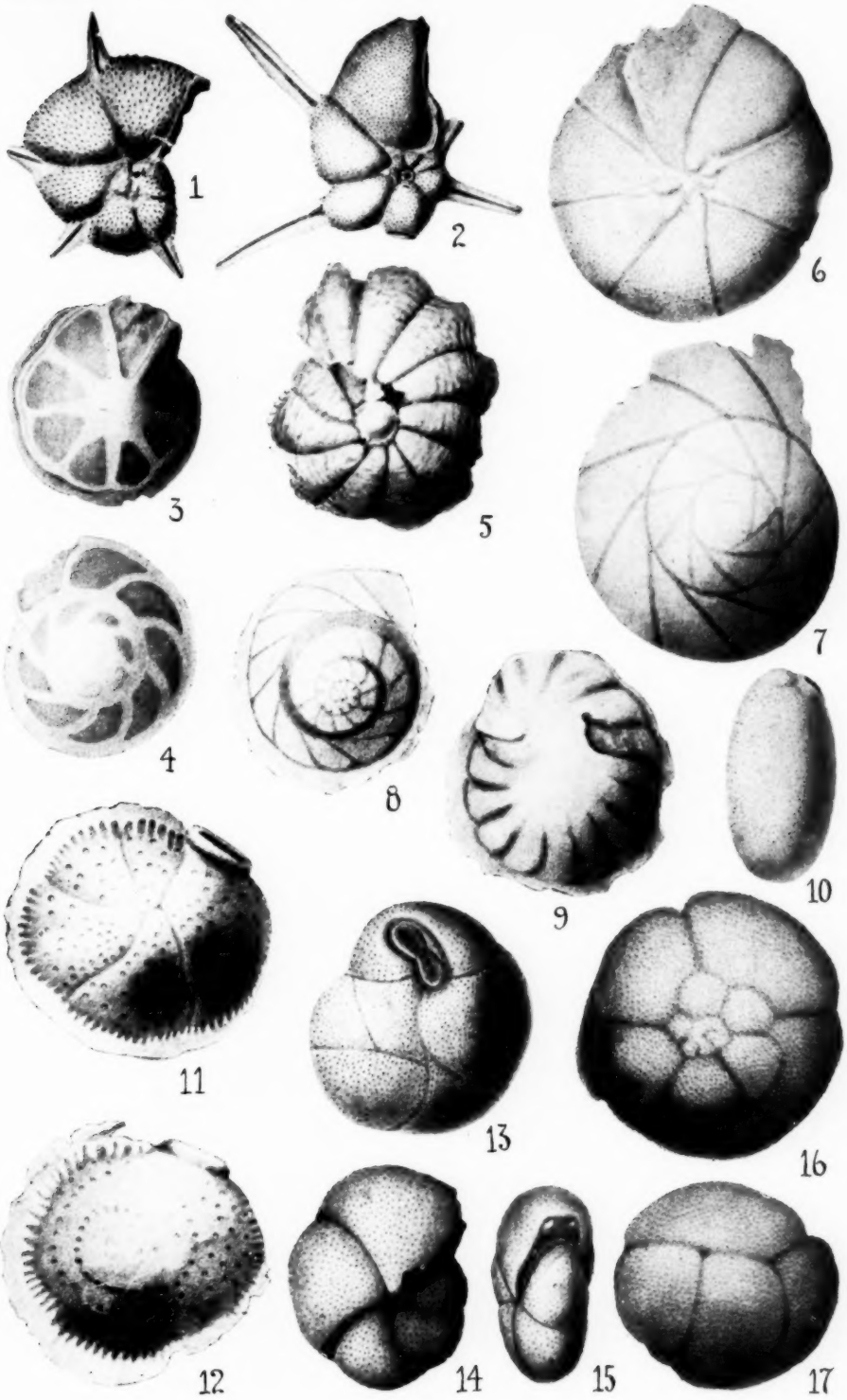
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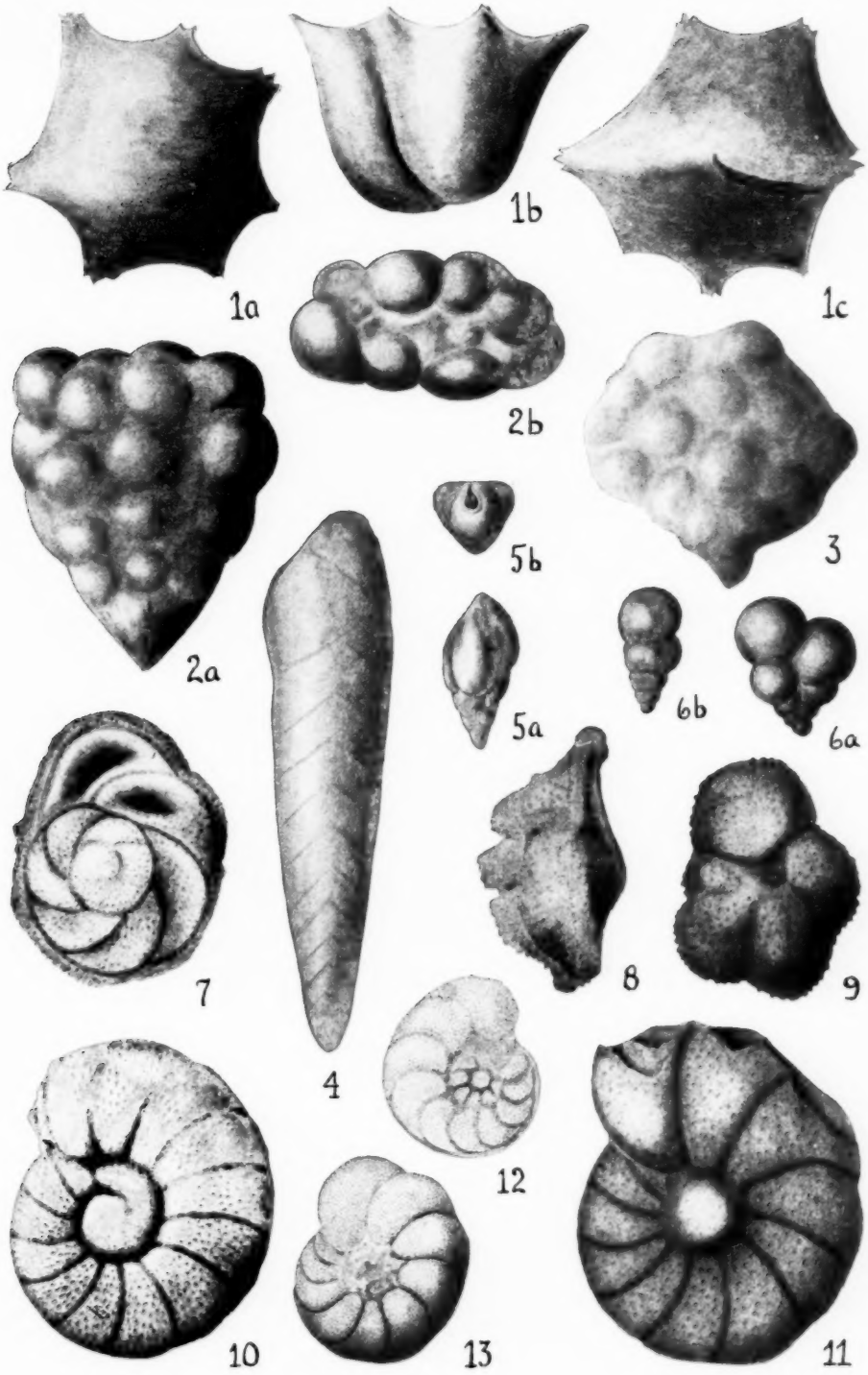
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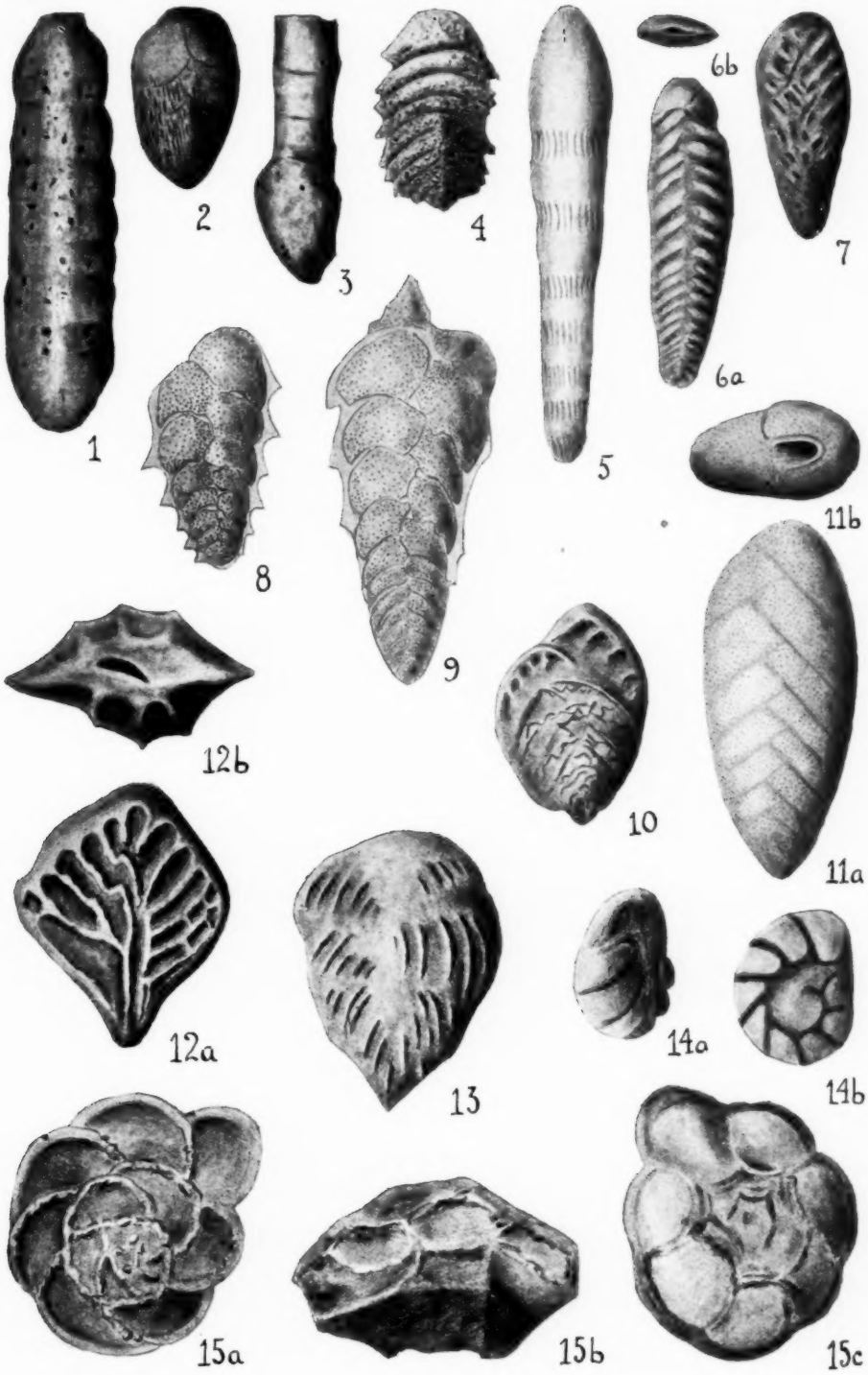
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NEW FAUNAL EVIDENCE FROM THE TENSLEEP FORMATION

A. E. Brainerd and I. A. Keyte

During the summer of 1925, the senior author made a detailed measured section on Sheep Mountain, 9 miles north of Grey Bull, Wyoming. In 1926, both authors visited this locality and added considerably to the collections made in 1925.

A section which accompanies this article gives the detail from the top of the Madison limestone up through the Amsden and Tensleep and for about 500 feet into the red shales, limes, and gypsum beds above the Tensleep.

This paper deals particularly with collections found in Zones A and B, as shown on the accompanying section. A brief statement is made, concerning Zones C and D, which lie above the Tensleep formation.

The Tensleep formation, as here measured and mapped, has a thickness of 36 feet and is composed of the typical buff, medium-grained sand so characteristic of the formation. At the top of the sand there is a zone of chert from a few inches to a foot thick, which is quite fossiliferous. This zone is marked "B" on the section. The fossils are exceedingly clear cut and distinct. The following forms were collected from this zone: Crinoid stems, Bryozoa—two unidentified forms, *Fenestella*—three species, Gastropods—two unidentified forms, *Ambocoelia planoconvexa* Shumard, *Squamularia perplexa* McChesney, *Marginifera* cf. *M. wabashensis* N. and P., *Productus cora* d'Orb., *Spirifer rockymontanus* Marcou, *Phillipsia major* Shumard.

Zone A carries *Productus cora*, *P. semireticulatus*, *Spirifer triplicatus*, and *S. rockymontanus?* These forms occur in a gray to purplish limy shale, which is nearly a lime, and in a thin-bedded sandy shale of the same color.

Zone C is a thin-bedded, gray lime in the red shales and carries many small unidentified pelecypods.

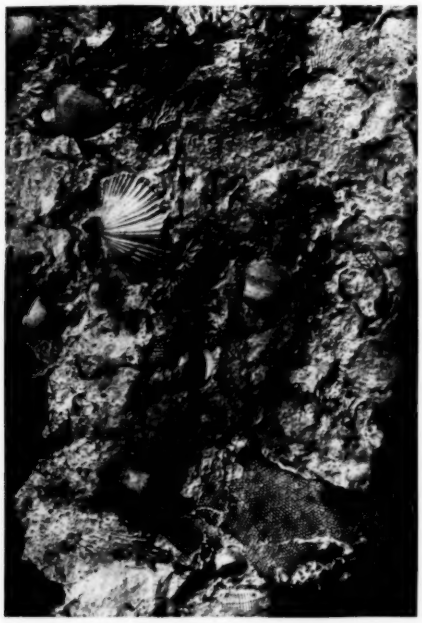
Zone D is a massive gray limestone about 3 to 4 feet thick, which carries what appears to be a Pennsylvanian or Permian bryozoan.

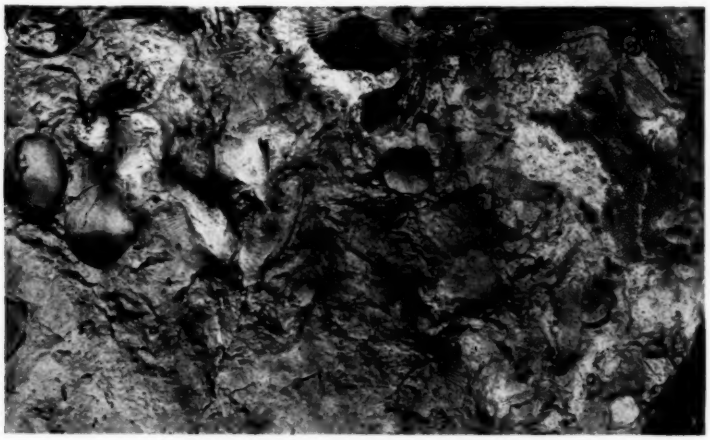
The forms from Zone B as a whole seem to indicate a position in the Mid-Continent Pennsylvanian section somewhere between the Fort Scott and the upper part of the Kansas City. In the Rocky Mountain section, its position seems to be equivalent to the lower Magdalena of New Mexico and the Hermosa of Colorado.

The few forms collected from Zone A indicate that it is of Pennsylvanian, but are not distinctive enough to place it accurately. The occurrence of sands below and above the shales of this zone suggests the possibility that this zone may belong with the Tensleep rather than with the Amsden, as it is now mapped. The forms found in Zones C and D have not as yet been accurately identified; and, although

they apparently belong to the Pennsylvanian or Permian, it is impossible as yet to be sure of the exact position.

Accompanying photographs (plate 29) of the chert from Zone B will show several of the various fossils and the mode of occurrence.

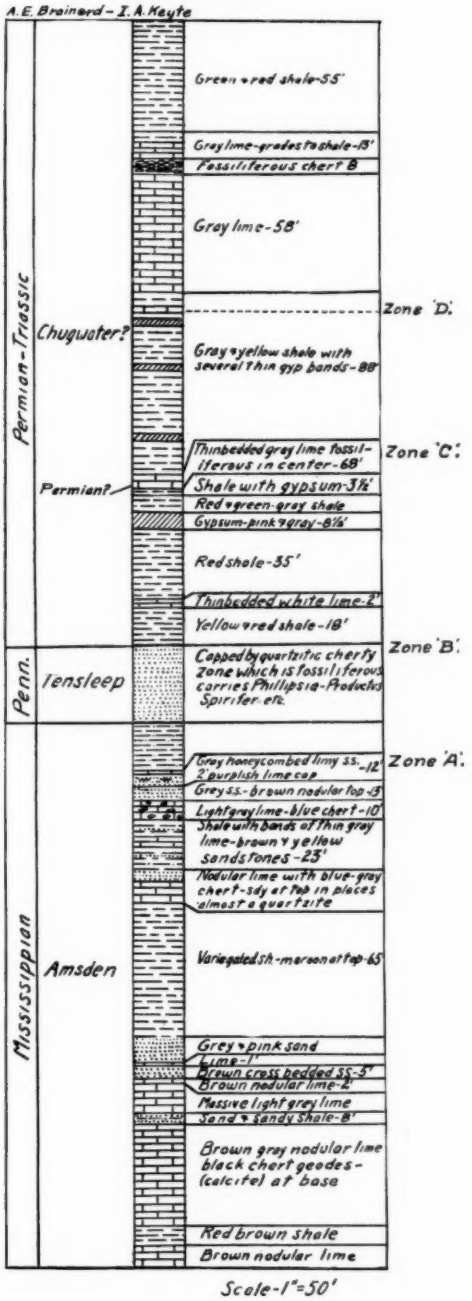




NEW FAUNAL EVIDENCE from the TENSLEEP

Section of Tensleep Sandstone Showing Higher and Lower Formations of Sheep Mountain, Wyoming T54N-R94W

A.E. Brainerd – I.A. Keyte



Scale-1"=50'

GAPTANK-WOLFCAMP PROBLEM OF THE GLASS MOUNTAINS, TEXAS

I. A. KEYTE, W. GRANT BLANCHARD, JR., AND HARRY L. BALDWIN, JR.

In 1917 Udden[1] described the above formations from the Glass Mountains, Texas. Böse[2] in the same year described the following ammonoids from Wolfcamp:

Daraelites texanus, n. sp.
Uddenites schucherti, n. gen. et sp.
U. minor, n. sp.
Gastrioceras modestum, n. sp.
Schistoceras diversecostatum, n. sp.
Paralegoceras incertium, n. sp.
Agathiceras frechi, n. sp.
Marathonites vidriensis, n. sp.
M. sulcatus, n. sp.
M. J. P. smithi, n. gen. et. sp
Vidrioceras uddeni, n. gen. et sp.
V. irregulare, n. sp.

The above fossils were collected from the zone of Uddenites at Wolfcamp. Udden states (p. 43):

Though the evidence is not quite clear, it is believed that there is an unconformity between the Wolfcamp and the Gaptank. As has been shown the upper part of the Gaptank is a thick limestone, which does not occur in a continuous exposure but caps some buttes that form a chain extending in front of the principal escarpment from Gaptank to a couple of miles west of Wolfcamp. Their appearance suggests that this limestone was once outliers capping buttes carved out of the Gaptank formation. There is a suggestion that the Wolfcamp extends down the edges of these capping limestones, but the evidence is not clear and so far no basal conglomerate of the Wolfcamp has been discovered.

The impression we get from the above is that Udden regarded the various limestone caps as the same limestone. In our studies of this formation we find that these limestones, that cap the outliers, are in most cases entirely different layers of the Gaptank, as shown by our columnar sections accompanying this paper.

At Wolfcamp, where Udden made his section 7, we would put the Gaptank-Wolfcamp contact at the top of layer 11, thus putting the Uddenites zone of Böse in the Gaptank. These fossiliferous shales and limestones can be traced along the base of the foothills for over 5 miles northwest toward Gaptank. The location where we collected the largest fauna is 4 miles northwest of Wolfcamp, at the foot of the slope; at this place only a few fragments of ammonoids were found; but following this layer about a mile east, great quantities of ammonoids were found, including:

Uddenites schucherti Böse
Schistoceras diversecostatum Böse
Marathonites J. P. smithi Böse
Daraelites texanus Böse
Schistoceras aff., *S. fultonense* (Miller and Gurley)
Gastrioceras aff. *G. globulosum* M. and W.
Gastrioceras aff. *G. kansasense* (Miller and Gurley)
Gastrioceras aff. *G. marianum* Verneuil
Pronorites aff. *P. cyclobus* Phillips.

[1] *Univ. of Texas Bull.*, no. 1753.

[2] *Ibid.*, no. 1762.

Associated with these ammonoids are:

Pustula semipunctata (Martin)
Hustedia mormoni (Marcou)
Ambocoelia planiconvexa McChesney
Productus cora d'Orb.
P. costatus? (Sowerby)
Lophophyllum profundum M. and H.
Eupachycrinus magister M. and G.
Composita subtilita (Hall)
Spirifer triplicatus (Morton)
Chonetes granulifer Owen
Marginifera splendens? (N. and P.)
Euomphalus pernodosus M. and W.
Rhombopora lepidodendroides? Meek
Cladopora?

and numerous others that have not been identified. Probably the most abundant fossil is the *Cladopora?*, which is so plentiful at Udden's fossil locality at Wolfcamp; but it is more abundant 2 miles northeast of Wolfcamp at the foot of the Gaptank exposure. The Uddenites zone 5 miles northeast of Wolfcamp is over 400 feet below the top of the Gaptank. While a few of the ammonoids were collected from the shale, nearly all of those we collected there were in a very impure limestone that contained very few brachiopods, many gastropods, a few pelecypods, *Lepidodendron*, and charcoal and plant impressions. There are a number of fossiliferous limestones above this layer, all of which contain regular Pennsylvanian fauna.

The Wolfcamp formation overlies the Gaptank from about 2 or 3 miles northeast of Wolfcamp to a mile or more west of Wolfcamp. This formation is very fossiliferous about 1 mile northeast of Wolfcamp. One specimen of *Delocrinus major* Weller was found at this locality, which would indicate a close relationship to the base of the Cibolo formation; the remainder of the collection was sent to Dr. Girty for identification, but no reply has as yet been received except that those from the Uddenites zone were Cisco fossils.

The Wolfcamp is probably absent 3 to 6 miles northeast of Wolfcamp—no fossiliferous Wolfcamp was found between there and Gaptank—but it probably is represented by the series of sandstones, shales, and conglomerates overlying the Gaptank just west of the highway, as they apparently change to the shales and limestones that contain Wolfcamp fauna when the highway crosses the formation.

The relation of the upper and lower Gaptank is yet to be determined; the lithology is somewhat similar, except that the shales and sandstones predominate in the lower, while shales and limestones predominate in the upper. The fauna is distinctly different, the lower, that of Canyon age; the upper, Cisco. Dr. Beede[1] has identified a fauna from the lower Gaptank and correlated it with the coal measures of Kansas.

There may have been a continual deposition from Canyon to Cisco in this region, but nowhere in this locality have we found an outcrop that we thought contained both upper and lower Gaptank. (Note: Blanchard believes that the outcrop ½ mile south of Gaptank contains both upper and lower Gaptank.)

There is a possibility that the upper and lower Gaptank may prove to be two distinct formations; based on faunal evidence they should be so divided.

[1] *Ibid.*, no. 1753, p. 39.

The following is a list of fossils from the lower Gaptank, collected 3 miles south and east of Gaptank:

Fusulina secalica Say
Girtyina sp?
Axophyllum rude St. John and Worthen
Campophyllum torquium? (Owen)
Lophophyllum profundum M-E. and H.
Chaetetes milleporaceus Troust
Crinoid plates and stems
Echinocrinus sp.
E. ourayensis Girty
Rhombopora lepidodendroides? Meek
Stenopora tuberculata Prout
Ambocoelia planoconvexa Shumard
Aulacorhynchus millepunctata (M. and W.)
Chonetes geinitzianus Waagen
C. mesolobus N. and P.
Cleiothyridina orbicularis (McChesney)
Composita subtilita (Hall)
Derbya crassa M. and H.
D. bennetti Hall and Clarke
Enteletes waggeni Gemm.
Enteletes sp.
Hustedia mormoni (Marcou)
Marginifera muricata N. and P.
M. ingrata Girty
Marginifera sp?
Meekella striatocostata (Cox)
Productus coloradoensis Girty
P. cora d'Orb.
Productus sp.
Pustula nebraskensis (Owen)
P. pertenuis (Meek)
Pustula sp?
Rhipidomella pecosi Marcou
Spirifer rockymontanus (Marcou)
S. triplicatus (Morton)
Spiriferina kentuckyensis Shumard
Squamularia perplexa McChesney
Aviculopecten hertzeri Meek
Deltopecten sp?
D. vanvleeti Beede
Nucula anodontoides Meek
Sanguinolites?
Schizodus cuneatus Meek
Schizodus sp.
Bellerophon, several species
Naticopsis ortoni Whitfield
Pleurotomaria granulostriata M. and W.

In addition to the above, Beede reports from the same locality:

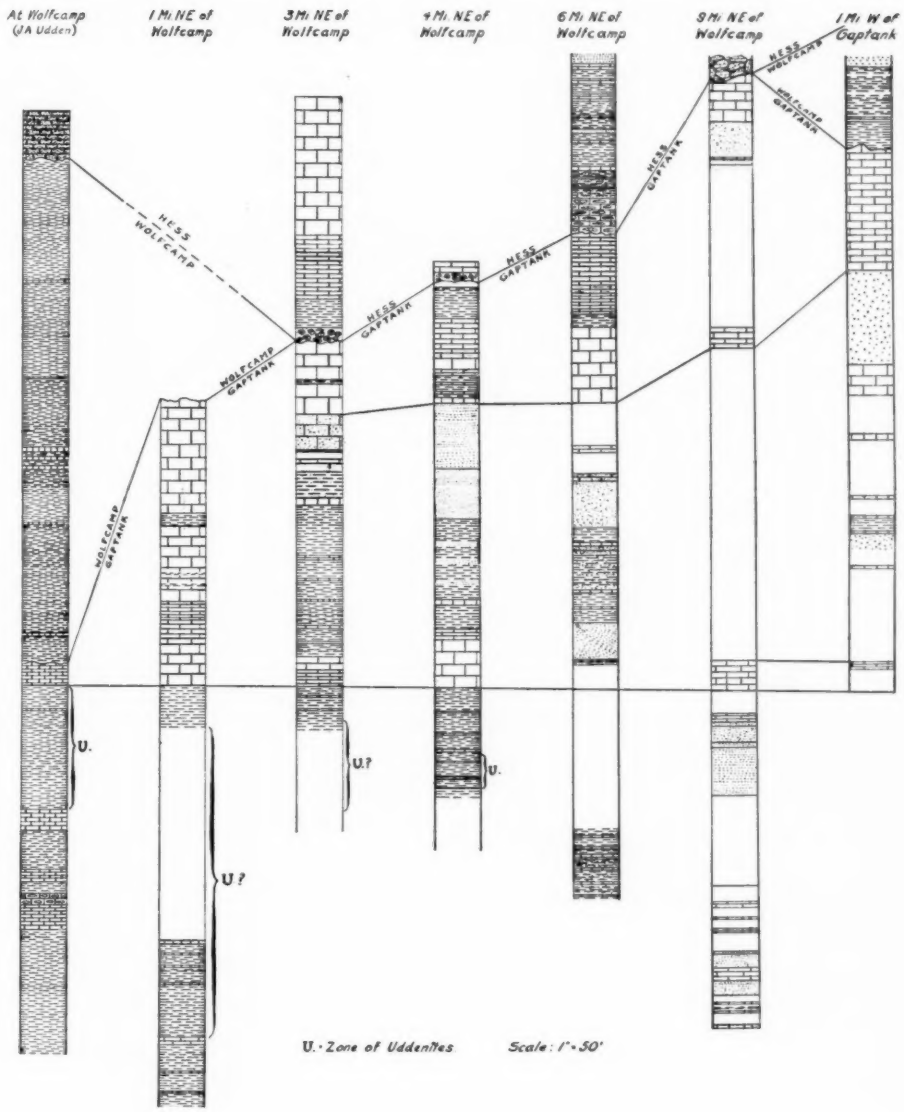
Axophyllum
Chaetetes sp.
Heterocoelia aff. *H. beedi* Girty
Several species of *Productus*
Coelocladia? sp.
Chonetes verneuilianus N. and P.
Wewokella sp.
Composita cf. *C. mexicana* Girty
Composita cf. *C. mexicana guadaloupensis* Girty
Meekella cf. *difficilis* Girty
Pugnax rockymontana (Marcou)
Spirifer musakheylensis Dav.
Chenomya leavenworthia Meek
Nuculopsis ventricosa (Hall)
Bellerophon percarinatus Conrad
Bellerophon tricarinatus Shumard
Bellerophon crassa M. and W.
Euphemus nodocarinatus White
Euphemus cf. *E. carbonarius* Cox
Pleurotomaria
Group of *P. altaica* Vern.
Porcellia sp.
Trachydomia wheeleri (Swallow)
Trachydomia sp.
Trepospira cf. *T. illinoiensis* Worthen
Worthenia aff. *W. tabulata* Conrad.

From the above data, we offer the following conclusions:

That this region was elevated, folded, and faulted in late Pennsylvanian time, followed by a long period of erosion, resulting in peneplanation of this region, after which the Wolfcamp was deposited in Permian seas. This region was again elevated, or the adjacent territory depressed, causing most of the Wolfcamp to be eroded before the Hess seas invaded this part of Texas. The zone of Uddenites

400 feet below known Gaptank is the same as that of the Wolfcamp locality; hence the ammonoids described by Böse from the Wolfcamp are Pennsylvanian. The upper Gaptank is Cisco, the lower Gaptank is of Canyon age.

This paper is intended to add a little to the geology of the Glass Mountain region and possibly stimulate a more detailed study toward its ultimate solution.

GAPTANK-WOLFCAMP PROBLEM.
GLASS-MOUNTAINS, TEXAS.

J. A. Keyte, W. Grant Blanchard Jr., Harry L. Baldwin Jr.